the official journal *Sovietskaya Geologiya* (Anon., 1939*a*, pp. 17–18) 135-x
castigated the unsatisfactory, even dangerous condition of the Soviet 439
graphite industry during these years.

433x

Loss of the Ukraine during World War II deprived the U.S.S.R. of more than one-third of its graphite output (4,000 m.t. at Zaval'sk and 3,600 m.t. total at Mariupol' 1 and 2). Only the Kyshtym and Krasnoyarsk plants (4,000 m.t. each) remained, in addition to the large but high-cost Igarka operation (6,000 m.t. annual capacity). Denial of Ukrainian flake graphite was an especially heavy blow. The once-rich Botogol mines in Eastern Siberia (Usova, 1929) had long ago been exhausted; the only available source was one deposit discovered in 1939 at Taiginskoye near Kyshtym (Bogdanovich, 1941). Nevertheless, the loss of most Soviet steel and aluminum output eased demand; the recovery of these industries and the increasing availability of nonferrous metal supplies then led to higher and higher Lend Lease imports. In both 1941 and 1942 the United States shipped 150,000 lb of natural graphite; in 1943, 2,360,000 lb; and in 1944, 2,101,000 lb. Shipments of graphite and carbon products during the same years were 569,000 lb, 9,078,000 lb, 16,354,000 lb, and 16,798,000 lb (Bureau of the Census, 1944, n.d., 1946*a*, 1946*b*).

In addition to U. S. shipments, the United Kingdom sent 3,300 tons of graphite between October 1941 and March 1946, inclusive (*Mineral Trade Notes*, vol. 22, no. 6, p. 49, June 1946). By 1944, therefore, the deficiency of Soviet domestic graphite supplies was some 9,500–10,000 m.t.

Postwar information on Soviet graphite output is completely lacking, but, as mentioned previously, the atomic-energy program has undoubtedly had a strong positive effect upon that industry.

Consumption and Utilization of Graphite. Clearly, the Soviet 433x
Union has used natural graphite on a scale far exceeding American 135-x
practice, being in this regard much more comparable to Germany and the United Kingdom. In general, the Soviet demand trend seems to run close to 2.5 times Hypothetical Standard, i.e., about 2,500 m.t. in 1926, 5,500 m.t. in 1932, and 13,500 in 1937. During World War II, however, the rapid increase of aluminum and copper fabrication based upon Lend Lease supplies, and the maintenance of cast-iron production at a high rate, probably required continuing

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*/135 *433 the 1937 consumption level. It is not impossible that the Soviet consumption of finished graphite reached 25,000 to 30,000 m.t. by 1950.

An approximate utilization pattern for graphite can be worked out from scattered Soviet and American sources and from known Soviet production trends in cast-iron, electrical-steel, and ferroalloy smelting, and nonferrous metallurgy (Table 67).

Certain points in regard to Soviet graphite practice are of interest. The graphite content in carbon blacking, a product used in the lubrication of molds for casting, declined sharply between 1935 and 1947. In the former year, nonferrous-grade blacking required 90–100 per cent graphite; in the latter, 53.4 per cent; again, cast-iron grades formerly were set at 35 to 60 per cent, and later at 9 to 17 per cent (Veselovskii, 1935, p. 118; Kumanin, 1947, p. 99). Furthermore, the acute Soviet shortage of crystalline graphite for crucibles during World War II forced the substitution of modified cast iron, particularly as a container for smelting aluminum (Landa, 1945, p. 166). In contrast, interest in graphite crucibles even for steel manufacture had reawakened by 1946; the basic problem was to increase the life of the linings, which was only 6 to 14 castings, and particularly short for high-manganese steels. The linings utilized a mix of 20 to 30 per cent graphite, 15 to 14 per cent chamotte, 20 per cent quartzite (sand), and the remainder clay. Kyshtym graphite, with 91.8 per cent C, but screening only 31 per cent over 0.09 mm in particle size, and Mariupol' (Staryi Krym) graphite, with 57 per cent C, screening 50 per cent over 0.09 mm in particle size, were used (Budnikov and Zeitlin, 1946).

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TABLE 67

Approximate Soviet utilization of graphite (metric tons)

Use	*1926–1928*	*1932*	*1937–1944*
Cast iron (carbon blacking)	1,000	3,575	5,200
Electrical steel	—	225	1,800
Electrical ferroalloys	—	100	1,000
Crucibles and retorts	1,000	1,000	4,000
Other	500	600	1,500
Total	2,500	5,500	13,500

Sources: Veselovskii, 1935, pp. 120 ff; Budnikov and Zeitlin, 1946; Kumanin, 1947; ***Minerals Yearbook***, 1947, p. 1267.

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135x 45

Satellite Graphite Production. Northern Korea has had a steadily increasing significance as a graphite producer since 1927. About 15 per cent of its output has been usually crystalline, the rest amorphous. Both types are of excellent quality. Total production rose from 22,750 m.t. in 1933 to 43,600 in 1937, according to Meisner (1939, p. 357); and 58,000 m.t. in 1944, according to *Mineral Trade Notes* (vol. 23, no. 2, p. 48, August 1946). (See also Friedensburg, 1938, pp. 322–323.) Such an output would fully cover both Soviet and satellite needs in the postwar period.

The graphite resources of Czechoslovakia, once a major producer, seem to be largely exhausted (Meisner, 1939; Friedensburg, 1938; p. 436).

135x 316

Graphite Reserves and Deposits. Soviet graphite reserves are difficult to assess with confidence. In the first place, reserve estimates were drastically reduced from 1937 to 1939. Estimates as of January 1, 1937 (Andreyev, 1939) were: measured, 35,142,000 m.t.; indicated, 162,958,000 m.t.; total, 1,100,264,000 m.t. Corresponding estimates as of January 1, 1939 (Betekhtin, 1946) were: measured, 17,117,000 m.t.; indicated, 9,327,000 m.t.; total 1,085,330,000 m.t. And full reserve estimates by deposit are available only for 1937, with fragmentary figures for later years. In the second place, information on the quality of the graphite in deposits is most incomplete. In the third place, new discoveries have been made in the Urals, at Kyshtym and Poltavka, for which adequate quantitative and qualitative accounts are lacking. Nevertheless, it is clear that even the most conservative evaluation of Soviet graphite resources shows them to exceed considerably the Hypothetical Standard needs of the U.S.S.R. to 1970, some 650,000 m.t. of commercial graphite (70–100 per cent C).

The most important producers of graphite in the U.S.S.R. have been the Petrovo deposits near Dnepropetrovsk in the Ukraine, characterized by (largely small) flake graphite averaging 10 per cent carbon content in the ore. Actually, the ores of the Pre-Cambrian graphite gneiss run from 5 to 15 per cent C, while occasional lenses of 20 to 50 per cent C have been found within the harder enclosing ores (Andreyev, 1939; Semenenko, 1937). As of 1937, Andreyev assessed the measured reserves of the Petrovo group at 1.72 million m.t., and total reserves, at 24.6 million m.t. But Merenkov and Muratov (1942 pp. 65–74) reduced total reserves

x/135
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at Petrovo proper to 4.82 million m.t., including 252,000 m.t. of 19 per cent C, 3 million of 9–10 per cent C, and the remainder only 6–7 per cent C. Nearby deposits were given total reserves of 464,000 m.t. (4–8 per cent C). Thus gross estimates of reserves for the Petrovo group have fallen from 24.6 to 5.28 million m.t. The Zaval'sk group of deposits on the Bug River, also in the Ukraine, is characterized by small flake graphite (0.1 to 2 mm). As at Petrovo, the ores are developed in Pre-Cambrian biotite gneisses. The presence of significant quantities of calcite in the graphite is an unfavorable quality of the Zaval'sk ores. Aggregate measured reserves for the entire Zaval'sk region were 692,000 m.t., with total reserves of 3.52 million m.t. (Merenkov and Muratov). However, because the deposits are characterized by up to 85° dip, with considerable sections below the Bug River, it appeared unlikely as early as 1937 that much of the total reserves could be utilized. Despite its low content and small size, the Pre-Cambrian Staryi Krym deposit near the sea of Azov (Ukraine) has been important as a source of large flake graphite (1 to 30 mm). In 1937, measured reserves here were stated to be 346,000 m.t., with total reserves of 663,000 m.t., of 4 to 6 per cent average carbon content in the ore. (See also Serdyuchenko, 1935.)

In the Urals, the main exploited deposit has long been that at Boyevka, which is characterized by low-grade amorphous graphite. Its average carbon content is 26.86 per cent, with high quartz adulteration (34.01 per cent) and considerable sulfur content (0.21 per cent). As of January 1, 1937, measured reserves at Boyevka were 119,800 m.t., with total reserves of 186,500 m.t. In 1939, however, a deposit of excellent flake graphite (up to 2 mm) was discovered near Kyshtym (Taiginskoye) in the Urals. Although the average carbon content of the ore is but 3 to 4 per cent, experiments in concentration appeared highly satisfactory. A concentrate of 95–96 per cent carbon content was obtained, with a 50 per cent yield of metallurgical graphite. No figures on reserves are available; production is known to have been started here during World War II (cf. Bogdanovich, 1941). Also of potential significance has been the discovery of sizable quantities (inferred reserves, 1937, 1.42 million m.t.) of amorphous graphite enclosed in Carboniferous anthracites at Poltavka, in the Urals. The graphite ore is of high quality, with 89.96 per cent C, 0.23–0.12 per cent S; small amounts of crystalline graphite have also been found. This deposit is not yet known to be in operation. 135-X 316

The amorphous-graphite deposits of the Lower Yenisei (Eastern Siberia) are the largest and finest in the Soviet Union. Geologically, they represent Upper Carboniferous or Permian coal seams subjected to profound contact metamorphism from the action of diabase intrusions. The Kureika deposit alone was assessed in 1937 (Andreyev, 1939) (and confirmed by Merenkov and Muratov, 1942) at 8.6 million m.t. of measured, and enormous inferred, reserves. The carbon content averages 84.5–90.6 per cent; ash, 5.72–14.30 per cent, of which, unfortunately, 23.5–32.0 per cent is SiO_2, and 33.5–62.7 per cent $Al_2O_3 + Fe_2O_3$. Estimates for Noginskoye (1937) were 1.97 million m.t. of operating reserves and 10 million m.t. of inferred reserves. Although lower in carbon (84.4 per cent C), Noginskoye graphite seems freer than Kureika from harmful admixtures in the ash. Finally, Fatyanikha, with 78,800 m.t. of planning reserves and 3,250,000 m.t. of inferred reserves, as of January 1, 1937, is marked by extremely pure graphite: 90 per cent C, 0.04 to 0.11 per cent S. Despite the size and quality of the Yenisei deposits, their inaccessibility has forestalled large-scale development. According to the Third Five-Year Plan, their graphite-ore production was to rise from 2,000 m.t. in 1938 to 15,000 m.t. in 1942 (cf. Yanson, 1937).

In the Far East, two important graphite deposits are known. Soyuznoye, the larger, was stated to have measured ore reserves of 20.8 million m.t., and total reserves of over 1 billion tons as of January 1, 1937. The ore runs from 7 to 22.5 per cent C, with an average of 17 per cent. As stated previously, recovery in 1939 was 19 per cent of the carbon content, or 3.3 per cent of the total ore. Bira, although smaller, has the advantage of being located on the Trans-Siberian railroad. Its ore reserves, as of January 1, 1937, comprised 264,000 m.t. of planning (A) reserves and 1.4 million m.t. of indicated reserves. The average carbon content is 5 per cent, but the ore is suitable for concentration. In neither of the Far Eastern deposits has the character of the graphite been clearly delineated; at least a portion is small to large flake graphite.

Gypsum. Summary. Soviet gypsum output reached 1,212,000 m.t. in 1937, four times that of 1926; the target for 1950 was some 2.7 million m.t. Foreign trade in gypsum has not been recorded. Consumption, which appears thus to have equaled production, dropped 135-x 433+ 316

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316

from 107 to some 60 per cent of Hypothetical Standard between 1926 and 1928, and then recovered to the earlier relative level by 1937. These levels of supply have never been enough to satisfy Soviet needs, because the high rate of industrial construction has required the entire gypsum output and more, starving agriculture, the chemical industries, and ceramics. The high concentration of output (despite widespread resources) and very high transportation costs to consuming areas were apparently inhibiting factors in the industry. During World War II, furthermore, the most important quarries, in the Ukraine, were damaged; by 1944, however, restoration and large-scale net increase in gypsum-producing capacity were being initiated.

Soviet gypsum resources are abundant for any conceivable needs; in addition, important deposits of gypsum also occur in Eastern Germany, while Rumania has a small gypsum output. Information on the gypsum resources of the other satellites is lacking.

Production of Gypsum. In 1926, the U.S.S.R. produced 291,600 m.t. of marketable gypsum, virtually all from four groups of deposits: Artemovsk in the Ukraine (43.5 per cent), Ust' Kama on the middle Volga (29.2 per cent), Gor'kii-Filinskoye in Central Russia (13.7 per cent), and Kungur in the Urals (3.3 per cent) (Geological Committee, 1927, pp. 115–122). Production dropped to 241,000 m.t. in 1928, then increased again to 475,000 m.t. in 1932 and 856,000 m.t. in 1935 (Shneider, 1948, p. 32; State Planning Commission, 1937, pp. 92 ff). By 1937, raw-gypsum output had risen to 1.7 million m.t., with a marketable yield of 1,212,000 m.t. Although several new deposits were now in operation, at Zvoz, Nizhnii Baskunchak, Ufa, and Agdzhakend, the Artemovsk quarries in the Ukraine remained the largest producers. According to Shneider, European Russia, excluding the Urals, produced 75 per cent of the national total in 1938; the Urals must be credited with most of the remainder. Localized production in combination with high-cost transportation led to great differences in local gypsum prices. Thus, in 1940, Grade I gypsum cost 42 rubles per metric ton in the eastern Ukraine, 104–159 rubles in Moscow, Leningrad, and the Uzbek S.S.R., and 510 rubles in Yakutiya (Shneider, 1948, p. 35). Such price differences unquestionably reduced the national market for gypsum. World War II led to the temporary loss of the Artemovsk and Zavalye quarries, with possibly a quarter of the country's output. However,

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a directive in 1944 (Shneider, 1948) ordered that Artemovsk be 135x
restored to 500,000 m.t. annual capacity, and that Ust' Kama and 433x
Syukeyevo on the Volga each be expanded to 600,000 m.t.;
Baskunchak, to 200,000 m.t. The planned capacity of Stalinogorsk, 316
the sole underground operation, was to be 1.2 million m.t. of raw gypsum. Thus, the postwar gypsum output of the U.S.S.R. has been planned much more ambitiously than in the past, for a total of possibly 2.7 million m.t. of marketable gypsum in 1950, although the evils of overlocalized output are still evident. Actual achievements since the war are not known. No record of Soviet imports or exports of gypsum has been found.

Consumption and Utilization of Gypsum. As mentioned earlier, 339
industrial construction demands, specifically for Portland cement and 433x
building plaster, have equaled or even exceeded Russia's gypsum 135x
output — striking evidence of the scale of Soviet investment over the past twenty-five years. This can be established not only from qualitative statements such as Shneider's but by examination of the course of Soviet cement output: 1.33 million m.t. in 1926; 1.90 in 1928; 3.47 in 1932; 5.45 in 1937; 5.80 in 1940; 3.50 in 1946, and 10.6 in 1950 (TsUNKhU, 1932, p. 6; 1935, p. 217; State Planning Commission 1939, p. 204; Bergson *et al.*, 1949, p. 56, extended by claims of annual percentile increases, cf. Central Statistical Administration; 1947–1951). Portland-cement manufacture requires 0.32 per cent gypsum; furthermore, the ratio between cement and gypsum output in industrial and housing construction varies little from 4:1. Finally, at least 65 per cent of Soviet cement goes into factory, building, and housing construction, judging from the data on ferrous-metals input (Chap. III, Sec. 1; see also *Minerals Yearbook*, 1940, p. 1117). On this basis, the calculated Soviet gypsum demand for cement and building plasters alone equaled 87 per cent of the total supply in 1926, 150 per cent in 1928, 140 per cent in 1932, 78 per cent in 1937, and — if Soviet plans have been achieved — 75 per cent in 1950. The deficit of gypsum, especially during the First Five-Year Plan, undoubtedly had a serious effect on the quality of Soviet construction.

Gypsum Reserves and Deposits. Soviet gypsum reserves are very 135x
large. According to Gubkin (1938*e*), operating (A_2) reserves alone totaled 231 million m.t. as of January 1, 1936, and measured reserves, 1.25 billion m.t. Total reserves were incompletely estimated at some

x/35 3 billion tons. Against these reserves, Soviet Hypothetical Standard requirements to 1970 aggregate but 91.5 million m.t. The gypsum deposits of European Russia are almost all Paleozoic (Devonian or Permian); only Zavalye in the Ukraine and the Transcaucasian deposits are Mesozoic. In contrast, the deposits of Turkestan and Eastern Siberia appear all to be Mesozoic (Betekhtin, 1946, pp. 391–395).

All Soviet economic regions except Western Siberia and the Far East have gypsum deposits of appreciable size. The more significant include Zvoz in North Russia, with 26 million m.t. measured and 108 million m.t. total reserves. In Northwestern Russia is Porkhovo, with 6.9 million m.t. measured and 10.3 million m.t. total reserves. In Central Russia are the bulk of Soviet measured reserves, 702 and 163 million m.t. at Stalinogorsk and Gor'kii-Filinskoye, respectively. The Volga region holds the large Nizhnii Baskunchak deposit (113 million m.t. measured and 406 million m.t. total reserves), plus three smaller sites at Ust' Kama, Syukeyevo, and Alekseyevskoye. In the Ukraine are the large Artemovsk and the smaller Zavalye deposits; the first has 63.5 million m.t. measured and 186.6 million m.t. total reserves, the second, 0.5 and 15.3 million m.t. The reserves of Kungur-Yergachinskoye in the Urals include 14.1 million m.t. measured and 31.9 million m.t. total; those at Ufa, in the same region, are not known. The North Caucasus deposit of Uchkur aggregates 52.2 million m.t. of measured reserves; Agdzhakend and Khudoni in the Transcaucasus, 10.9 and 15.4 million m.t. measured, about 11.3 and 28.6 million m.t. total. The resources of Turkestan are limited to the small deposits of Urangai and Muravyevskii Zaliv, totaling 7.9 million m.t. of measured reserves. Finally, Zalari, in Eastern Siberia has been assessed at 3.5 million m.t. measured and 13.7 million m.t. total reserves.

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Magnesium Minerals: Magnesite and Dolomite; Magnesium Salts. Summary. The U.S.S.R. has long had an extremely high output and consumption of magnesite (increasingly, also of dolomite) as a refractory in the iron and steel industry. This has permitted the capacity use, at high temperatures, of metallurgical furnaces. In blast-furnace practice, this policy has permitted over 20 per cent more output of pig iron than would otherwise have been possible. (But see also Chap. III, Sec. 1.) Inasmuch as Soviet magnesite resources are abundant and accessible, their lavish use appears to be

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thoroughly justified. Dolomite has been used primarily in the 135-x
Ukraine and Central Russia, where the proximity of deposits to 433x
consumers has apparently justified its use despite lower refractory 327
properties than those for magnesite. Among the satellite states in Europe, Czechoslovakia is known to have exportable surpluses of magnesite; East Germany's moderate output fails to cover its needs. On the other hand, Manchuria has the world's largest resources, so that the Soviet sphere as a whole is extraordinarily strong in magnesite supplies.

In 1926, the U.S.S.R. was producing but a fraction of its needs 135-x
in magnesium salts, supplying most of its small consumption through 316
imports. The development of the carnallite deposits at Solikamsk, on 433x
the western flank of the Urals, permitted full self-sufficiency in later years, including the period of World War II; unfortunately, quantitative data on Soviet magnesium-salts output after 1926 are unavailable. It is known, however, that these salts have been the major raw material used for the production of metallic magnesium in the U.S.S.R. While quantitative data of any reliability are also unavailable, it is evident that the output of metallic magnesium has grown rapidly since its start in the middle 1930's. During World War II, 431
the U.S.S.R. required moderate imports of metallic magnesium; at the end of the war, however, it stripped much greater capacity from Germany than was needed to cover its wartime deficit. Soviet magnesium-salts resources at Solikamsk are virtually unlimited; those controlled in Eastern Germany are also enormous.

Magnesite and Dolomite: Production and Consumption. In 1926, 433-x
the U.S.S.R. produced 103,017 m.t. of crude magnesite, of which it 135-x
exported 1,059 m.t., leaving a net consumption of 101,958 m.t., nine times the Hypothetical Standard level. From the magnesite consumed, the following products were recovered: metallurgical powder, 27,669 m.t.; magnesite brick, 12,055 m.t.; and caustic magnesite, 2,079 m.t. (the last being for Sorel cement). Dolomite production was also relatively large, 179,203 m.t. (2.7 times Hypothetical Standard). Although a quantitative breakdown of its utilization is not available, a large proportion of the output was also consumed by ferrous metallurgy. Magnesite production was concentrated exclusively in the Urals (Satka), but 70 per cent of Soviet dolomite came from two Ukrainian deposits: Yama and Nikitovka. (Cf. Geological Committee, 1927, pp. 189–192, 355–361.)

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By 1937, Soviet magnesite output had risen to 846,000 m.t., of which 800,000 came from Satka and the remainder from Khalilovo, also in the Urals (Betekhtin, 1946, pp. 306, 311). Exports totaled only 3,880 m.t. of calcined magnesite, leaving a net consumption of some 838,000 m.t. of raw magnesite (cf. Meisner, 1939, p. 378). Thus Soviet magnesite consumption grew more rapidly from 1926 to 1937 (8.2 times) than did either pig iron (6.6 times) or steel output (6.0 times); in the latter year it exceeded the Hypothetical Standard level by 8.3 times. Furthermore, dolomite consumption had also grown; in 1937, it "considerably" exceeded 1 million m.t.; of this total, some 800,000 m.t. were produced in the Ukraine (Potapenko, 1946, pp. 11, 43).

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The utilization of magnesite and dolomite for metallurgical purposes may be computed approximately from data provided by Potapenko (1946, p. 23), Kilesso (1947, p. 28), and the State Planning Commission (1936, II:434–435). Apparently, some 175,000 m.t. of metallurgical powder for open-hearth steel-furnace linings, about 101,000 m.t. of magnesite brick, plus 91,000 m.t. of caustic magnesite were recovered in 1936. In steelmaking, the relation of magnesite powder to dolomite consumed differed sharply between the Ukraine and the Urals and Siberia, namely, 3.8–9 kg of magnesite powder and 18–68 kg of dead-burned dolomite per ton of steel in the former, and 8–32 kg of magnesite powder with only 8–32 kg of dead-burned dolomite in the latter two. In general, it appears that, while magnesite and probably dolomite consumption per ton of steel remained stable between 1926 and 1937, their utilization in blast-furnace linings for pig-iron and ferroalloy production rose rapidly. For magnesia brick alone, the consumption per ton of pig iron and ferroalloys rose from 5.4 kg in 1926 to 7.0 kg in 1937. Such high and yet increasing consumption resulted from extremely intensive use of blast furnaces at high temperatures. This permitted a great increase of pig-iron output per unit of blast-furnace capacity, albeit at a corresponding decrease in the life of furnace linings. According to Pavlov (1948, p. 27), this life, prior to World War II, was usually under three years. Nevertheless, considering the fact that the recovery of pig iron from blast-furnace charges in the Soviet Union has been low because of large losses in iron-ore fines, and considering also the Soviet desire to maximize pig-iron output, the results obtained appear creditable, as can be seen from Table 68.

Another factor leading to the large and growing consumption of 433x
magnesite brick in Soviet blast furnaces has been their increasing 327
size. In the late pre-World War II period, the average output per 135x
blast furnace for the entire country was some 180,000 m.t. (compared with an average American capacity in 1940 of 224,000 m.t.). But the Soviet total included 15 small charcoal furnaces as compared to only 4 for the United States. Actually, 32 furnaces in the U.S.S.R., with capacities of 828 to 1300 m³, produced 75 per cent of the nation's pig iron and blast-furnace ferroalloys, averaging about 340,000 m.t. per furnace per year. The blast furnaces constructed in recent years, such as Magnitogorsk Number 6, are of the 1,300-m³ class, with a daily capacity of 1500 m.t. of pig iron. (Pavlov, 1948, pp. 40–41; American Iron and Steel Institute, 1941, p. 4.)

TABLE 68

Blast-furnace operation in the Soviet Union, the United States, and Germany, about 1940

Country	*Number of Furnaces Sampled*	*Pig Iron Recovered from Charge (per cent)*	*Daily Pig-Iron Output per Unit Capacity* (m.t./m³)*	*Average Heat Time (hr)†*
U.S.S.R.	11	40.1	1.03	8.4
U.S.A.	8	45.3	0.97	9.7
Germany	7	43.3	0.96	9.7

* Nominal 100 per cent capacity, about 1.17 m.t./m³.
† Excluding charcoal furnaces.
Source: Pavlov, 1948, pp. 47, 50, 54, 59.

Data on Soviet magnesite and dolomite output during World War II and since are unavailable. Presumably, production fell during the war in response to lessened demand from a war-devastated iron and steel industry, and has since recovered to about prewar levels. In 1944, the U.S.S.R. exported 992 short tons of crude, and 5396 short tons of dead-burned, magnesite to the United States (DeMille, 1947, p. 279). Finally, although no dolomite and little if any magnesite was being consumed for the production of metallic magnesium as late as 1946–47, the U.S.S.R. had removed from Germany in 1945 magnesite-process plants with a capacity of 14,000 m.t. of metallic magnesium annually. These may now be installed near Satka in the

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Urals. (See Potapenko, 1946, p. 19; Kilesso, 1947, p. 28; *Mineral Trade Notes*, vol. 21, no. 2, pp. 21–22, 1945.)

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Magnesite and Dolomite: Satellite Output and Resources. As was mentioned earlier, Manchuria is a major producer of magnesite, exporting 401,000 m.t. in 1938; its reserves of high-grade magnesite aggregate hundreds of millions of tons (Juan, 1946, p. 465; Betekhtin, 1946, p. 309). Czechoslovakia produced 91,000 m.t. of crude magnesite in 1937, exporting about half; its reserves are unknown. Finally, Eastern Germany satisfies only part of its needs locally, depending heavily on imports: in 1942, raw magnesite output totaled only 25,407 m.t., against 55,808 m.t. consumed (Betekhtin, 1946, p. 306; *Mineral Trade Notes*, vol. 21, no. 2, p. 35, 1945). Statistics on dolomite output or reserves in Eastern Europe or Manchuria and Korea are lacking.

x/135

Magnesite and Dolomite Reserves and Deposits. Soviet reserves of both minerals are clearly large, obviating any anxiety about supplies for an indefinite period. Yet the survey of dolomite deposits has proceeded slowly, so that the developed reserves are but a fraction of those geologically inferred.

As of January 1, 1933, Soviet reserves of magnesite were computed at a total of 251 million m.t., of which 85.7 million m.t. were measured (Tatarinov and Dvorshchan, 1935). Betekhtin, in 1946 (p. 309), gave a much larger figure of 630 million m.t. for total reserves. Although these reserves are scattered through the southern Urals, Kazakhstan (Turkestan), and the Middle Amur region of the Far East, only two large and excellent deposits, both in the southern Urals, appear to be mined today. Satka, a deposit formed by hydrothermal action of magmatic origin upon dolomites, consists of an ore body at least 1200 meters long, and 80–110 meters thick, to depths of 150 and 300 meters. The quality of the magnesite is stated to be excellent, with low iron content. As of January 1, 1933, measured reserves aggregated 84.2 million m.t., with total reserves of 150 million m.t.; by 1938, measured and indicated reserves comprised 185 million m.t. The smaller Khalilovo deposit of amorphous magnesite is genetically associated with a highly weathered serpentine core. The ore is therefore very variable in composition, averaging 3 per cent magnesite, of which the average composition in turn includes 46 per cent MgO, 1.6 per cent CaO, and 0.5 per cent SiO_2. Total reserves were over 4 million m.t. as of January 1, 1933.

Merenkov and Muratov (1942, p. 115), however, give only 350,000 m.t., possibly applicable to but one ore body. 135x

The best-quality dolomites for refractory purposes in the U.S.S.R. appear to be associated with Permian marine deposits (particularly the Kungur formation), which are found from the White Sea to the Volga, in the Ukraine, and near Vladivostok in the Far East. However, the great abundance of magnesite in the U.S.S.R. has deterred thorough assessment of these resources. The reserves of the operating quarries in the Ukraine — Nikitovka and Yama — aggregate 65 and 9.3 million m.t. respectively (Betekhtin, 1946, p. 389).

Magnesium Salts and Metallic Magnesium. Until the development 135x of the great carnallite and sylvite deposits of the Solikamsk group 433x (Urals), the U.S.S.R. was sorely deficient in magnesium-salts production. Its sole source in 1926 was the brines of Sakskoye Ozero in the Crimea, with an annual capacity of 1,250 m.t. of $MgCl_2$ and 66 m.t. of magnesia. Actual output in that year was but 967 m.t. of $MgCl_2$ and 58 m.t. of magnesia; this was supplemented by 1,195 m.t. of imported $MgCl_2$ and 194 m.t. of $MgSO_4$, but the total supply was far below demand, officially estimated at 5,870 m.t. of magnesium salts (Geological Committee, 1927, pp. 351–354).

The production of potassium salts from Solikamsk began in 1931, and the carnallite workings began sometime thereafter. The output of magnesium salts from Solikamsk carnallite is not available; it should be mentioned, however, that no imports of such salts were needed from the United States, Canada, or the United Kingdom during World War II.

According to the *Minerals Yearbook* (1937, pp. 640–642), Soviet production of metallic magnesium began in 1936, carnallite and Sakskoye Ozero brine being utilized by plants at Berezniki and on the Dnepr, respectively. Production in 1937 was said to be 400 m.t., augmented by 43 m.t. of imports, yielding a total supply of 90 per cent of Hypothetical Standard. For 1943, the Bureau of Mines' estimate of Soviet metallic magnesium output is 5,000 m.t. (DeMille, 1947, p. 296). In view of the limited scale of Lend Lease magnesium shipments to the U.S.S.R. — none in 1941 or 1942, 3,293 m.t. in 1943, and 4,542 m.t. in 1944 — and high Soviet aluminum consumption during the war years, this estimate appears much too low. In my opinion, an output of 10,000 to 15,000 m.t. of magnesium in 1944 is more likely. This view finds some substantiation from the following

X 6.32
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facts: in 1945, the U.S.S.R. removed from Germany a total of 32,000 m.t. of magnesium-producing capacity (18,000 m.t. $MgCl_2$ process; 14,000 m.t. magnesite). Yet the Soviet output goal for 1950 was but 2.7 times that of 1945. (See Bureau of the Census, 1944, n.d., 1946*a*, 1946*b*; *Mineral Trade Notes,* vol. 21, no. 2, pp. 21–22, 1945; Lomako, 1947.)

Solikamsk, the sole carnallite-producing deposit in the U.S.S.R., consists of a series of Permian sedimentary deposits overlaid by 2 to 30 meters of Post-Tertiary sands and clays, and underlaid by Upper Carboniferous oil-bearing limestones. Within the Permian formations, the upper strata consist of 50–200 meters of limestones, clays, and gypsum; then comes salt (0–80 meters), and next the productive formations: 20–110 meters of carnallite and 12–50 meters of sylvite. Finally, comes a massive deposit of salt, 250 to 400 meters thick. The magnesium chloride content of Solikamsk carnallite varies considerably, averaging 22 to 25 per cent. The reserves are almost inexhaustible; they are estimated at 18 billion m.t. (Betekhtin, 1946, pp. 340–341).

The significance of the equally great carnallite deposits in Eastern Germany has been lessened by Soviet removal of their magnesium-producing plants. The fate of the small magnesium plants in Manchuria and North Korea, which produced 402 m.t. and 1,628 m.t., respectively, in 1944, is unknown (*Minerals Yearbook*, 1946, p. 731).

Talc and Pyrophyllite. Summary. Prior to World War II, the U.S.S.R. had a rapidly growing but still very inadequate output of talc and steatite. This permitted less than 50 per cent of Hypothetical Standard consumption by 1937, the paint and paper industries being completely bereft of supplies. Although subsequent Soviet production is not known, it is probable that a significant rise in production has taken place as a result of the introduction of (4= flotation at the main deposit, Shabry in the southern Urals. No imports of talc during World War II have been recorded. Furthermore, postwar control of Manchuria should have eliminated any residual shortages; Manchurian exports of talc totaled 111,140 m.t. in 1937. In contrast, Eastern Europe appears deficient in talc, although Finland and Rumania have been minor producers. Soviet reserves of talc are modest and low-grade; steatite is, however, abundant to cover the country's Hypothetical Standard needs beyond 1970. The

deposits are concentrated in the southern Urals and, to a minor 135x
extent, the Transcaucasus. 433x

As late as 1946, Soviet production of pyrophyllite, a partial substitute for talc, was insignificant and spasmodic. The sole presently known large deposit, aggregating "millions of tons" of reserves, is Suran in central Kazakhstan. The pyrophyllite here appears to be of good quality, with 65.0–66.6 per cent SiO_2, 26.3–28.6 per cent Al_2O_3, 0.75–1.20 per cent TiO_2, and only 0.04–0.19 per cent Fe_2O_3 (Arshinov and Chernosvitov, 1946, pp. 13–14, 28).

Production, Foreign Trade, and Consumption of Talc. In 1926, 433x
Soviet talc output was but 2,995 m.t. Imports of powdered talc com- 135x
prised another 817 m.t., so that consumption aggregated 3,812 m.t. 437
or 40 per cent of Hypothetical Normal. Details on the pattern of talc utilization in this year have not been found (Geological Committee, 1927, pp. 687–688).

By 1937, talc and steatite production had risen to 25,636 m.t., including 11,954 m.t. of powdered talc, 10,322 m.t. of talc (steatite) bricks, and 3,360 m.t. of block steatite. Imports were apparently lacking. Consequently, the country's needs could be satisfied at less than 50 per cent of Hypothetical Standard. Thus, while the supply of bricks and blocks for furnace linings appeared to be satisfactory, that of talc powder was sorely deficient. Neither the paint nor the paper industries received any at all; other allocations included 2,750 m.t. for construction, 2,630 m.t. for agriculture (particularly insecticides), 2,510 m.t. for rubber, 715 m.t. for ceramics, 595 m.t. for toilet preparations, and 2,750 m.t. for miscellaneous purposes (Betekhtin, 1946, pp. 300–301). By American standards, all but the allocation for insecticides were very small. According to Ural'skii, Shrader, and Medvinskii (1939, p. 74), the 1938 requirements of the paper and paint industries alone were 40,000 m.t. and 30–35,000 m.t. of talc, respectively.

The basic weakness of the Soviet talc industry during these years 433x
was technological. The only major steatite deposit in Russia, Shabry, 135x
was exploited solely for dimension bricks and blocks, with a recovery of only 30 per cent of the raw material (Ural'skii, 1938, p. 52). All talc powder came from a series of small talc deposits, the most important being Keryabinsk, with 420,000 m.t. of total reserves in 1927 (Geological Committee, 1927, p. 689). The supply of talc was

X/135 therefore very inconstant, so that even the modest factory at Miass, X433 then the only one in the U.S.S.R., could not approach its capacity of 20,000 m.t. per year (Ural'skii, 1938, pp. 60–61). A solution to these problems was advanced by Ural'skii and his associates in 1938–39 (Ural'skii *et al.*, 1939). They advocated treatment of Shabry steatite by the wet separation of magnesite, grinding with porcelain balls, and washing with weak sulfuric acid to produce talc and magnesite of 85–99 per cent and 78–80 per cent purities, respectively. The recoveries achieved in pilot operations approximated 86 per cent of the talc content or 43 per cent of the ore, plus 84 per cent of the magnesite content. The installation of such flotation would lower talc-production costs in the U.S.S.R. in 1937 by 60 per cent, and, above all, provide a firm source of raw materials for greatly expanded output (Ural'skii, Shrader, and Medvinskii, 1939, pp. 69–74). Whether these plans were put into operation is not known; the absence of talc imports during World War II, mentioned previously, suggests such action.

[439] *Satellite Talc Output.* Information on talc, steatite, or pyrophyllite reserves in the Soviet-dominated areas of Europe and the Far East is lacking. Nevertheless, the continued importance of Manchuria as a talc producer, with exports of 42,891 m.t. in 1931, 80,326 m.t. in 1936, and 111,140 m.t. in 1937, indicates important resources (*Minerals Yearbook*, 1935, p. 1076; *ibid., Review of 1940,* p. 1294; Juan, 1946, p. 466). In Eastern Europe, Rumanian and Finnish production for 1936 measured 2,529 and 1,683 m.t., respectively. But these industries suffered greatly from World War II, with Rumanian output in 1946 falling to 267 m.t., and Finnish, to 300 m.t. (*Minerals Yearbook, Review of 1940*, p. 1294; 1947, p. 1145).

X/135 *Talc Reserves and Deposits.* Soviet resources of coarse-grained talc, primarily of low grade, comprised 1,393,000 m.t. of measured and 5.0 million m.t. of total reserves, as of January 1, 1939. On the same date, measured steatite reserves comprised 75 million m.t.; total reserves were 245 million m.t. (Betekhtin, 1946, p. 303). Against these reserves, Soviet Hypothetical Standard requirements to 197 would aggregate 7.6 million m.t.

All of the Soviet talc and steatite deposits in the southern Urals the only ones of commercial significance, appear to have a common geological origin. According to Betekhtin (1946, p. 303), they arose from the alteration of serpentines through hydrothermal action of granitic-magmatic origin. As previously mentioned, Shabry is by far the largest deposit. Its measured ore reserves in the middle 1930's were 43 million m.t.; total reserves were 69 million m.t. The average composition of the ore, according to Ural'skii, Shrader, and Medvinskii (1939, p. 68), runs 29.7–32.4 per cent SiO_2, 31.0–36.5 per cent MgO, 0.97–2.0 per cent Al_2O_3, 0.67–4.0 per cent Fe_2O_3, 2.45–9.56 per cent FeO, 0.0–2.0 per cent CaO, 0.6–3.65 per cent H_2O, and 22–30 per cent CO_2. This corresponds to a talc content of some 49 per cent. The neighboring large deposit of Syrostan is characterized by a closely similar ore; it is not known to be in operation. Finally, the Keryabinsk deposit, with reserves of 420,000 m.t. in 1927 as stated earlier, has a variable ore composition. Steatite with inclusions of chlorite and magnetite is predominant, although the scattered lenses of coarse-grained talc (up to 0.5–1.0 m^3 in volume) and of very pure steatite have especial commercial significance (Merenkov and Muratov, 1942, pp. 100–101). The numerous other talc deposits near Keryabinsk are small. 135x

3. *Heavy Chemicals and Fertilizers*

Borax. In 1926 almost all of the Soviet borax supply, 3,855 m.t. or 93 per cent of Hypothetical Standard, came from imports; domestic production totaled but 1.6 m.t., from Crimean muds. However, the discovery of the Inderskoye borax deposit in 1935 alleviated dependence upon imports. Domestic output rose from 5,100 m.t. of borax in that year to 22,000 m.t. in 1938. This latter production, equivalent to 8,100 m.t. of pure B_2O_3, came from the mining of some 15,000 m.t. of rich ores (23.4 per cent B_2O_3), and 230,000 m.t. of lean ores (2.1 per cent B_2O_3) (Geological Committee, 1927, pp. 85–89; State Planning Commission, 1935*a*, p. 125; 1939, p. 176; Betekhtin, 1946, pp. 343–350). 439 433x 135x 316

Soviet imports of borax ceased in the early 1930's; yet the 1938 domestic output was equal to only 48 per cent of Hypothetical Standard consumption. At the same time, information to indicate later substantial increases in borax production is lacking; the only further evidence of imports was the American shipment of 721,000 lb of boric acid in 1942 (Bureau of the Census, n.d.). Evidently, the U.S.S.R. is content with a very low consumption of borax. No evidence of borax reserves has been found for the European or Asiatic Soviet satellites. 439 433x 135x x/135 Known Soviet borax resources are inadequate to cover even an extrapolation of low recent demand to 1970, let alone Hypothetical Standard requirements. Excluding the small datolite — Ca(BOH) SiO_4 — deposits of the North Caucasus and the very low-content borax-bearing muds of the Crimea and the Taman' Peninsula, Soviet borax resources are confined to two localities: Inderskoye in northwestern Turkestan, and Klyuchevskoye-Dimitriyevskoye in the Transbaikal region of Eastern Siberia. Inderskoye consists of a large Permian gypsum cap (averaging 50–60 meters thick) overlying earlier Paleozoic formations. Within this cap, over 60 borax-bearing lenses have been discovered, predominantly associated with gray, clayey gypsum. The lenses are of two types: undisturbed, with 20 to 30 per cent B_2O_3 content, and disseminated, with 2 to 5 per cent B_2O_3. The two largest lenses are 250 to 300 meters in diameter and 8 to 18 meters thick. As of January 1, 1937, total ore reserves included 408,000 m.t. of rich ore (19.6 per cent B_2O_3) and 6.78 million m.t. of lean ore (3.5 per cent B_2O_3) (cf. Gubkin, 1938*b*). By January 1, 1939, the reserves of high-grade ores had been reduced by mining to 383,000 m.t.; of lean ores, to 6.43 million m.t. (Betekhtin, 1946, pp. 343–350). Since 1939, both further mining and new discoveries of lean ores at deeper horizons have been made, so an exact estimate of reserves at Inderskoye is not possible.

The quartz-tourmaline pegmatites of the Klyuchevskoye-Dimitryevskoye region, with an average mineral content of 2.25 per cent, have an indicated reserve of 200,180 metric tons of B_2O_3. Such ores are not considered to be commercial sources of B_2O_3 outside of the U.S.S.R.

[439]
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Iodine. In 1926, the U.S.S.R. was dependent on imports for almost all of its iodine needs, which were officially estimated at 100–150 m.t. Only 285 kg of iodine were produced domestically in that year, compared to imports of 106 m.t. By 1934, however, production had risen to 90.4 m.t. (TsUNKhU, 1936, p. 178), evidently eliminating imports. Subsequent production is not known, but appears to have been adequate for Soviet needs, as is evidenced by negligible Lend Lease shipments of iodine and iodides (Bureau of the Census 1944, n.d., 1946*a*, 1946*b*). Furthermore, the technical literature has never indicated any anxiety in regard to this mineral.

The sole known source of iodine in the U.S.S.R. is from oil-well waste waters, primarily from the lake Beyuk Shor near Baku (Transcaucasus) (Merenkov and Muratov, 1942, p. 171). However, the capacity of this one lake has been estimated at 400 m.t. annually — meeting even current needs without danger of exhaustion (Geological Committee, 1927, p. 288). Information on the availability of iodine from the satellite areas has not been found. 135-x 433x

Phosphate Rock and Apatite. Summary. Mining of the rich, large apatite deposits on the Kola Peninsula inaugurated significant Soviet phosphate minerals production in 1931. By 1937, Soviet consumption of phosphates, 2.1 million m.t., was tenfold that of 1927–28 and 77 per cent as great per acre as American; it was 300 per cent of Hypothetical Standard. Yet despite a large surplus of processing capacity, the shortages of sulfuric acid forced a quarter of Soviet phosphate consumption to be in the form of less desirable ground phosphate rock rather than superphosphates. Soviet exports of apatite concentrate reached 518,000 m.t. in 1937. 316 433x

During World War II, the destruction of most Soviet superphosphate-manufacturing capacity, in the Ukraine and Leningrad, plus the diversion of sulfuric acid to munitions output, reduced superphosphates output to possibly 20 per cent of the 1937 level of 1.45 million m.t. By 1950, production had risen once more, to 2.6 million m.t., somewhat below plan, and far below the plans for such earlier years as 1937 and 1942. The current output of ground phosphate rock is not known. In all, the Soviet phosphate input per cultivated acre in 1950 probably did not exceed 40 per cent the American in 1947, possibly 175 per cent of Hypothetical Standard.

The satellite production of superphosphates reached about its prewar level, between 400,000 and 500,000 m.t., in 1947–48. The meager postwar availability of Thomas slag, previously utilized in large quantities, has, in contrast, been a seriously adverse development. Except for Finland, which is not considered, Eastern European superphosphate output has depended almost solely upon imported materials — since the war, Soviet phosphate rock and Scandinavian pyrite.

Finally, the long-term possibilities of phosphate production in Russia are limited only by sulfuric acid capacities. By a conservative reckoning, Soviet phosphate-rock reserves exceed 9 billion m.t.

Production, Foreign Trade, and Consumption of Phosphate Rock

Production [illegible]

to 1937. In 1913, Russia depended largely upon imports of phosphate rock and superphosphates: 35,912 and 196,732 m.t., respectively. Domestic output totaled 11,700 m.t. of superphosphates and 32,800 m.t. of Thomas slag. Phosphate fertilizers were used mostly in the Baltic and other western provinces (Geological Committee, 1927, pp. 757–773). By 1926, Soviet consumption of phosphate had recovered only to a third of 1913's. But this consumption derived largely from domestic output: 73,516 m.t. of phosphate rock, utilized to manufacture 80,618 m.t. of superphosphate (ca. 14 per cent P_2O_5) and 5,700 m.t. of ground phosphate rock. The Ushitsy group of deposits in the Ukraine produced more than a third of the national total; other output came from Central Russia, the Volga, and the Urals. Thomas slag was no longer being produced, after the loss of Polish basic-process steel mills (Geological Committee, 1927, pp. 757–773). Thus, the Soviet consumption of phosphate rock in 1926, though 160 per cent of Hypothetical Standard, was only 5 per cent as great *per cultivated acre* as in the United States in the same year.

As previously mentioned, production of apatite — the active ingredient of phosphate rock — began at Kirovsk on the Kola Peninsula in 1931. The output of apatite concentrate climbed from 26,900 m.t. in that year to 156,500 m.t. in 1932 and 1,158,000 m.t. in 1937 (TsUNKhU 1936, p. 174; State Planning Commission, 1939, p. 205). Of these totals, 45,000 m.t. and 512,000 m.t., respectively, were exported (Bakulin and Mishustin, 1939; Meisner, 1939, p. 354). Phosphate-rock production climbed rapidly between 1926 and 1934, and then declined. Thus, its output aggregated 104,400 m.t. in 1927–28, 684,300 m.t. in 1932, 1,148,500 m.t. in 1934, and only 840,000 m.t. in 1937. The reason for this secondary decline lay in the displacement of lower-grade phosphate rock by apatite concentrate, in the manufacture of superphosphates. Consequently, while superphosphates output rose from 149,131 m.t. in 1927–28 to 615,649 m.t. in 1932, and 1,454,000 m.t. (18.5 per cent P_2O_5) in 1937, the use of phosphate rock for its production had been abandoned except at the Voskresensk and Perm' plants. These used select ores from the Yegoryevsk-Voskresensk-Bronnitsy and Fosforitnaya deposit groups, respectively. An additional small plant manufacturing fertilizer from northern Kazakhstan phosphates began operation at Aktyubinsk in 1937. The bulk of phosphate-rock production, however, was instead being used simply ground rather than chemically digested. The volume of this

product, which is of doubtful value as a fertilizer, according to Jasny 433x
(1949, p. 495 n.), increased from 12,700 m.t. in 1927–28 to 384,600 316
m.t. in 1932, and 634,000 m.t. in 1937. Finally, with the growth of 327
basic steel production at Kerch, the output of Thomas slag revived, reaching 24,484 m.t. in 1932 and 40,792 m.t. in 1935. In all, the input of phosphate rock and superphosphates into Soviet agriculture grew between 1927–28 and 1937 as shown in Table 69. It should be noted that fertilizer imports ceased in 1933.

Despite important Soviet progress prior to World War II, inadequate supplies of sulfuric acid held superphosphates production far below the capacity in being by 1936 — nominally, 2.72 million m.t., and practically about 2.18 million m.t. The main plants and their nominal capacities in 1936 were the following: in the Ukraine, Konstantinovka (680,000 m.t.), Odessa (225,000 m.t.), and Vinnitsa (270,000 m.t.); also, Leningrad in Northwest Russia (570,000 m.t.), Voskresensk in Central Russia (540,000 m.t.), Perm' or Molotov in the Urals (435,000 m.t.), and Aktyubinsk in northwest Turkestan (50,000 m.t., unfinished). (See Ames mss, after *Zhur. Khim. Prom.* 1936, No. 16/18, p. 199; State Planning Commission 1936, I:129–130, 580, 581.) The maximum prewar Soviet achievement was 1.65 million m.t. of superphosphates in 1938, contrasted to 1937–1942 goals of 3.3 million m.t. (Jasny, 1949, p. 495). By 1940, growing munitions requirements, competing for sulfuric acid, had forced a cut-back in superphosphates output to only 1,370,000 m.t.

TABLE 69

Soviet phosphate minerals consumption (thousand metric tons)

Year	*Super-phosphates*	*Ground Phosphate Rock*	*Thomas Slag*	*Total*	*Input per Cultivated Acre*	
					(kg)	*(% of U.S.)*
1927–28	228*	12.7	0	241*	0.84	12
1932	616	385	24.5	1025	3.25	45†
1937	1454	634	36	2124	6.40	77‡

* Includes 78,900 m.t. imported.
† Compared to U.S. consumption, 1926.
‡ Compared to U.S. consumption, 1937.
Sources: TsUNKhU, 1936, pp. 174–176, 294, 692–693; State Planning Commission, 1936, I:128–130; 1939, pp. 205–220; Betekhtin, 1946, p. 326; Jasny, 1949, pp. 495, 503.

Even in 1937, according to Jasny (1949, 497–498), the utilization

Even in 1937, according to Jasny (1949- 497-98), the utilization
x433 of phosphate fertilizers was limited almost wholly to sugar beets,
241 cotton, flax, and hemp. The following percentages of the acreages
387 planted to these crops were fertilized: 100 per cent, 43 per cent, 35
per cent, and 20 per cent respectively. Grain, potatoes, and vegetables received practically no commercial fertilizer.

x433 *Wartime and Postwar Changes in Phosphate Production.* The
x135 Soviet phosphate industry declined sharply during World War II.
316 The bulk, 64 per cent of Soviet superphosphate-manufacturing
capacity, in the Ukraine and Leningrad, was destroyed or rendered
inoperative, as can be seen from the data cited earlier. The Lend
Lease shipments via the Murmansk railroad shunted aside the supply
of apatite from Kirovsk. Finally, critical military needs for sulfuric
acid must have reduced the output of even the remaining capacity.
Thus, it is doubtful whether the production of superphosphates in
the U.S.S.R. averaged more than 200,000–300,000 m.t. annually during the war years. Yet the Soviets never augmented their domestic
[439] supplies of phosphates by Lend Lease shipments. The only imports
were of elemental phosphorus (1,860,000 lb in 1942), presumably
for the manufacture of incendiary projectiles (Bureau of the Census,
n.d.). Consequently, soil deterioration continued unchecked.

The Fourth Five-Year Plan anticipated raising Soviet superphosphates capacity to 3,034,000 m.t. by restoring the Ukrainian (to 860,000 m.t.) and Leningrad plants, and adding the following new production: 300,000 m.t. in the Uzbek S.S.R., 230,000 m.t. in the Kazakh S.S.R. and 50,000 m.t. in the Turkmen S.S.R. (cf. *Zakon o Pyatiletnom Plane*, 1946, *passim*; Korobov, 1946, p. 29). Superphosphates production in the last republics named, all of which are major cotton growers, was to be based upon the extensive Kara-Tau deposits in southern Kazakhstan. Exploitation of these deposits, discovered in 1935, began only in 1946 (Pomus, 1947, p. 1847). The total planned production for 1950 was 2,720,000 m.t. of superphosphates, plus 400,000 m.t. of ground phosphate rock (Jasny, 1949, p. 495; Vol'fkovich and Dubrovitskii, 1947, p. 1055). Actual superphosphates output in 1950, according to *Izvestiya*, 17 April 1951, was 1.9 times that of 1940, or some 2.6 million m.t.

Satellite Phosphate Needs. Phosphate-rock production in Eastern Europe has never been significant. According to Friedensburg (1938, pp. 368, 380), Polish output declined from 39,000 m.t. in 1929 to 12,000 m.t. in 1936; correspondingly, the peak of Rumanian production was 1,600 m.t. in 1929. Phosphorus-bearing basic slag has been more important; I estimate its total output to be some 300,000 m.t. annually. At the same time, superphosphates output in Czechoslovakia, Poland, Eastern Germany, and Hungary totaled some 400,000–500,000 m.t. in 1947 and 1948; in addition, Finland produced 154,000 m.t. in 1949 (*Statistical Yearbook of the United Nations 1949–50*, pp. 232–233). In all, the deficit that must be covered by imports — normally of phosphate rock from French North Africa (more recently, the U.S.S.R.) and Thomas slag from the Ruhr and Benelux (now unavailable) — is great. In 1926, it aggregated some 530,000 m.t. of phosphate rock and 1,200,000 m.t. of Thomas slag. (See Imperial Institute, 1928, pp. 258–266; Meisner, 1939, pp. 347–355.)

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316

No evidence of phosphate production or consumption in Manchuria or North Korea has come to light.

Phosphate Reserves and Deposits. Soviet phosphate resources total at least 9 billion m.t., abundant for the indefinite future. Britske (1937), Chirvinskii (1939), Svyatlovskii and Diterikhs (1939), Merenkov and Muratov (1942, pp. 15–22, 148–165), and Betekhtin (1946) have described the major deposits. Other details, including those on ore tenor and reserves, have been published by the Geological Committee (1927, pp. 757–774), Koz'min (1936), and Promtov (1935).

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Soviet phosphate deposits may be divided into four groups. The first consists of Mesozoic — predominantly Cretaceous — marine deposits at Yegoryevsk-Voskresensk-Bronnitsy (Central Russia), Shchigry (Central Russia), Fosforitnaya (Volga), and Aktyubinsk-Kazalinsk (Turkestan). In 1926, the measured reserves of all these deposits jointly included 245 million m.t. of rock carrying over 24 per cent P_2O_5, borne by an area of 1,523 km^2, with average productivities of 158–400 kg/m^2. For lower-grade rock, with 18–24 per cent P_2O_5, their reserves were far greater, 7.28 billion m.t., borne by an area of 24,215 km^2, with average productivities of 222–348 kg/m^2 (Geological Committee, 1927, p. 766). The other groups of phosphate deposits include the small secondary sediments of Ushitsy in the Ukraine; the large Cambrian, sedimentary (marine) deposits at Kara-Tau in southern Kazakhstan (Turkestan); and the Khibin group on the Kola Peninsula in Northwest Russia, derived from a Devonian alkaline intrusion into Archean gneisses.

The Yegoryevsk-Voskresensk-Bronnitsy group, some 50 miles south-

X/135

east of Moscow, covers a total area of 945 km^2, dissected by branches of the Moscow River. Two productive layers occur. The lower or Portland formation averages 0.3 meter in thickness, with a productivity of 360 kg/m^2 at an average content of 22.5 per cent P_2O_5. The characteristic ore is clayey. The upper or Upper Volga-Ryazan horizons aggregate 1.1 meters in thickness, with a productivity of 615 kg/m^2 at a content of 22 per cent P_2O_5. The phosphate particles in these horizons are coarser, ranging from sand to pebble-sized concretions. The measured reserves of the Yegoryevsk section of this deposit group are 85 million m.t.; total reserves, 195 million m.t. (Britske, 1937, pp. 44–50; Betekhtin, 1946, p. 333).

The Shchigry deposit near Bryansk in Western Russia represents a northern outcropping of the extensive Mesozoic phosphate formation, aggregating several billion tons, precipitated in the Donets-Dnepr graben. The deposit, covering an area of 40 km^2, has three productive horizons, of which the most important ranges in thickness from 0.4–0.65 meter. Its depth of only 6 meters facilitates stripping. The average content is 350 kg/m^2 of 16 per cent P_2O_5. The measured reserves in 1946 were about 14 million m.t., but inferred reserves are much larger. In 1936, this deposit produced 150,000 m.t. of ground phosphate rock, 27.5 per cent of the total Soviet output (Koz'min, 1936). Numerous similar but less developed deposits are found within a radius of 20 miles from Shchigry.

In the Kirov Oblast' of the Volga region, the Fosforitnaya group of deposits is marked by good-quality pebbly phosphate. The productive formation averages 0.7 meter in thickness; it bears 360–450 kg/m^2 with an average content of 27.5 per cent P_2O_5. Total reserves were estimated at 880 million m.t. (Anon., 1937*b*).

In the Aktyubinsk group of northwest Kazakhstan, phosphate deposition is confined to the Santonian sediments of the Cretaceous; the phosphorite horizon may, furthermore, be divided into two, the lower of pebblestone (up to 0.35 meter thick), and the upper of nodules and plates (from 0.5 to several meters thick) (Britske, 1937, esp. p. 69). In 1926, the measured reserves of this group comprised 389 million m.t. of 18–24 per cent P_2O_5, distributed over an area of 1,753 km^2, with an average productivity of 222 kg/m^2 (Geological Committee, 1927, pp. 757–774).

In the western Ukraine, secondary phosphate deposits deriving from the Mesozoic redeposition of Silurian sediments are found at

numerous small deposits east of the Ushitsy river. The high content 135x
of these deposits (35–36 per cent P_2O_5), plus their great productivity (up to 500–700 kg/m^2), stimulated their exploitation by the 1860's. However, the phosphate-bearing deposits lie relatively deep — from 120 to 210 meters — while aggregate reserves appear to be modest, probably not over 1 million m.t. Thus, these deposits have only a limited significance. (See esp. Britske, 1937, pp. 73–81.)

The discovery of important phosphate deposits at Kara-Tau in 1936 has profoundly improved the long-term prospects for agriculture in Central Asia. These deposits cover an area of 2400 km^2, and are characterized by a variable number of productive horizons, with aggregate thicknesses ranging from 0.6 to 30 meters, including phosphate-bearing silicas. The usual ore is coarse and firm; P_2O_5 contents range from 25 to 36 per cent, with an average of 28 per cent. In view of the great thickness of the productive formations, productivities per square meter of surface are very high, up to 25 m.t. The reserves of the four best deposits in this group — Kok-su, Ak-dzhar, Uch-bas, and Geres — are given by Betekhtin as 200 million m.t. According to Pomus (1947, p. 1847), the total reserves for the entire group are in excess of 1 billion m.t.

As stated previously, the apatite deposits of the Khibin group consist of two strata comprised within an intrusive body of nepheline magma. The first stratum, which is 75 meters thick, consists of a basic mass of apatite cemented together by pyroxene and titanomagnetite and dissected by breccia-filled fractures. The P_2O_5 content ranges from 22 per cent to 35 per cent. The second stratum, about 100 meters thick, is more constant in composition and texture than the first. It ranges from 49 to 60 per cent apatite, 25 to 35 per cent nepheline; the P_2O_5 content runs from 19 to 26 per cent. According to Promtov (1935), the apatite reserves at Khibin totaled 854 million m.t. as of January 1, 1933. By locality they comprised the following: Kukisvemchorr, 116.7 million m.t. of rich ore (29 per cent P_2O_5) and 146.6 million m.t. of lean ore (18 per cent P_2O_5); Yukspor, 142.7 million m.t. of ore (22 per cent P_2O_5); and Rasvumchorr and Apatitovyi Tsirk, 372.5 and 75.5 million m.t. of ore, respectively, of unspecified content.

Potash. Summary. Despite early knowledge of its large resources, 433x
Russia became a major producer of potassium salts only in the 1930's. 387
By 1937, its output of carnallite and sylvite totaled 2.4 million m.t., 135x

49: Shimkin E-4 (no date) 1953 R1 Soviet Union R1

x433 387 x135 containing 266,000 m.t. of K_2O. But the actual recovery of potash amounted only to 40–50 per cent of the content, and the fertilizer input per cultivated acre but 28 per cent that of the contemporary United States.

By 1940, Soviet potassium fertilizer output had risen another 50 per cent, almost certainly reflecting better recoveries. The course of wartime production is not known, but in 1945, the U.S.S.R. annexed the former Polish potash deposit. This acquisition, possibly combined with further progress in recovery, led to an output of some 850,000 m.t. of potassium fertilizer (41.6 per cent KCl?) in 1950. It is doubtful, however, whether this total (equivalent per acre to but 19 per cent of U. S. consumption in 1947) was all that available to Soviet agriculture, since the surplus of East German production over needs amounted even in 1946 to some 2 million m.t. of 11.8 per cent K_2O content. With reasonable technological progress since 1937, the Soviet output of potash, bromine, and metallic magnesium should not require more than the 1937 production of carnallite and sylvite, but actual postwar figures are completely absent.

In all, the Soviet world has an extremely strong potassium-minerals potential with virtually inexhaustible reserves both in the U.S.S.R. and in Germany. Any deficiency existing today could be ascribed only to mismanagement.

x433 x135 439 *Production, Exports, and Consumption of Potash.* In 1926, although the great Solikamsk potassium-salts deposit was already known, the nation's output was limited to 3,100 m.t. of potash recovered from sunflower ashes. Imports added another 2,000 m.t., giving the meager total supply of 5,100 m.t., under half of Hypothetical Standard and less than 2 per cent as much per cultivated acre as in the United States (Geological Committee, 1927, pp. 302–303).

The production of Solikamsk sylvite (22 per cent KCl) began on a significant scale, 120,000 m.t., in 1931 (TsUNKhU, 1936, p. 174). It then fell to 78,500 m.t. in 1932, rising again to 1,319,000 m.t. in 1935 and 1,585,000 m.t., averaging 22 per cent KCl content (*ibid.;* State Planning Commission, 1939, p. 205). Exports developed, although the pertinent information is incomplete. Shipments to the United States fluctuated widely: 3,974 m.t. of potassium chloride in 1934, virtually none in 1935 or 1936, 10,693 m.t. in 1937; 5,206 m.t. in 1938; 163 m.t. in 1939, and none in 1940 or 1941 (*Minerals Yearbooks,*

1934–1941). According to Friedensburg (1938, p. 405), total Soviet 433x
exports in 1936 approximated 40,000 m.t. of potassium chloride. The 135x
residues of unspecified, presumably potash, fertilizer exports given 439
by Bakulin and Mishustin (1939) are the following: up to 1931, none; 1931, 1,500 m.t.; 1932, 4,200 m.t.; 1933, 53,000 m.t.; 1934, 182,000 m.t.; 1935, 148,000 m.t.; 1936, 63,000 m.t.; and 1937, 150,000 m.t.

In addition to sylvite production, the Soviets began carnallite out- 433x
put at Solikamsk, primarily for bromine and magnesium salts. Be- 316
ginning at an insignificant level about 1932, production reached 135x
815,000 m.t., averaging 19 per cent KCl content, in 1937 (Betekhtin, 1946, p. 336, less sylvite production). Whether much potassium chloride was recovered from Soviet carnallites in prewar years is doubtful, since the total consumption of potassium salts by Soviet agriculture in 1937 was 402,000 m.t. of 41.6 per cent KCl fertilizer, or 93,100 m.t. of K_2O equivalent, half the quantity contained in the sylvite produced alone (State Planning Commission, 1939, p. 220). This consumption was reduced to 311,000 m.t. of fertilizer in 1938 (cf. Jasny, 1949, p. 495). It should be noted, furthermore, that 90 per cent of the Soviet potassium chloride recovered was consumed by agriculture (Chernyi and Fiveg, 1947, p. 19).

At the end of the war, the U.S.S.R. acquired the Stanislav (Stebnik) kainite-langbeinite deposits from Poland. These deposits had averaged 344,000 m.t. of output (with a K_2O content of 63,700 m.t. or 18.5 per cent) between 1927 and 1937 (Meisner, 1939, p. 99). Total Soviet potassium-fertilizer production rose to 40 per cent over the 1940 level, or about 850,000 m.t. in 1950, somewhat in excess of plan (Vol'fkovich and Dubrovitskii, 1947, p. 1055; *Izvestiya*, 17 April 1951).

Satellite Potash Production and Reserves. Between 1927 and 1937, 433x
German production of potassium salts averaged 10,744,000 m.t. 135x
(with a K_2O content of 1,264,000 m.t.) annually. Exports averaged [439]
37 per cent of total production (Meisner, 1939, pp. 100–101). German reserves of potassium salts aggregate 20 billion m.t., according to Betekhtin (1946, p. 336).

Total German output in 1946 was about 8,100,000 m.t., with a K_2O content of 955,400 m.t. (*Minerals Yearbook*, 1947, p. 1018). Of this total, some 78 per cent or 6.3 million m.t. may be ascribed to the Soviet Zone. Since this zone contains about half the arable land

+433 of Germany, its normal requirements would approximate 4 million
+135 m.t., leaving a surplus even in 1946 of at least 2 million m.t. Such a surplus would go far in covering any deficits of the U.S.S.R. and all its satellites. Korea, Manchuria, and China lack known resources of potassium salts.

+135 *Potash Reserves and Deposits.* All measured Soviet potash reserves are found in two deposit groups, Solikamsk-Berezniki in the Urals and Stanislav (Stebnik) in the western Ukraine. Solikamsk alone holds an estimated 18.5 billion m.t. of K_2O content, far beyond forseeable Soviet needs. It consists of Permian sediments overlaid by 2 to 30 meters of Post-Tertiary sands and clays. (See also the section on magnesium salts.) Within the Permian formations, the carnallite strata aggregate 20–110 meters in thickness; the underlying sylvite, 12–50 meters. The carnallite, though highly variable, averages 19.3–19.5 per cent KCl, 22 per cent $MgCl_2$, 27.5–31.5 per cent NaCl, 1.5–20 per cent $CaSO_4$, plus admixtures of clay, ferrous oxide, and bromine. It contains two-thirds of the reserves. The compositions of the sylvite run 24–42 per cent KCl, 52–71 per cent NaCl, and 1.0–2.2 per cent indissoluble precipitate (Chernyi and Fiveg, 1947, pp. 5 ff; Ivanov, 1935; Merenkov and Muratov, 1942, pp. 166–196).

The Stanislav deposit consists of lenses of a variety of potassium salts, especially kainite and langbeinite, interbedded with sodium salts, and developed in Miocene clays. The compositions of the kainite range as follows: K_2O, 11.4–13.2 per cent; KCl, 13.5–16.3 per cent; K_2SO_4, 2.3–5.4 per cent; $MgSO_4$, 26.9–34.2 per cent; NaCl, 26.4–32.4 per cent; plus $CaSO_4$, H_2O, and precipitate. The langbeinite averages 16.5 per cent K_2SO_4, 1.8 per cent KCl, 43.2 per cent NaCl, 26.9 per cent $MgSO_4$, the remainder being $CaSO_4$, H_2O, and precipitate (Chernyi and Fiveg, 1947). Total reserves approximate 50 million m.t. K_2O content (Betekhtin, 1946, p. 324).

Other small potassium deposits have been found in the Emba region of Kazakhstan and in Central Asia. Although the U.S.S.R. expressed considerable interest in them in 1939 (Anon., 1939*a*), it is possible that acquisition of the Stanislav deposit and the availability of potash from Germany have eliminated their significance in the immediate future.

x483 *Salt (Sodium Chloride). Summary.* Before World War II, the
x135 Soviet Union consistently overproduced salt, saturating the domestic

market, while only little could be exported. As a result, output 433x rose from 1.6 million m.t. in 1926 to a high of 4.35 million m.t. in 135-x 1935, and then was cut back to 3.2 million m.t. by 1937. In general, the industrial use of salt grew with unexpected slowness. Consequently, in contrast to the usual Soviet pattern, the consumption of salt by households and in agriculture rose from some 20 lb per capita (55–60 per cent of the American rate) to about 32 lb, between 1926 and 1937, while industrial consumption (normalized by the Index of Mineral Consumption) fell from about 140 per cent to 55–60 per cent of the American rate. Total consumption, reflecting Russia's large population, was 5.0 times Hypothetical Standard in 1926, and 1.8 times in 1937.

The Soviet salt industry, largely concentrated in the Ukraine, [258] may have declined further during World War II. The 1950 objective, only some 4.6 million m.t. (or 125 per cent of Hypothetical Standard demand), anticipated about 33 lb per capita consumption, plus industrial consumption at about 63 per cent the 1947 American rate. The output achieved is unknown, but industrial consumption was clearly below plan. Some imports from the satellites may also have been planned. While significant exports of salt by the Eastern European states are unlikely because of war damage to their salt industries and rising internal demands, Manchuria and North Korea may now be exporting salt to the Soviet Far East.

In both the Soviet Union and the satellites, the prospects for long-term adequacy in salt are excellent. Soviet reserves alone are virtually limitless; only in North Russia and Siberia do serious deficiencies in salt resources appear. In 1939, the former depended upon the Ukraine; the latter, upon the Pavlodar area in Kazakhstan and the Usolye brines near Irkutsk in Eastern Siberia.

Production, Foreign Trade, and Consumption of Salt. In 1926, the 433x U.S.S.R. produced 1.64 million m.t. of salt. Two deposits, Artemovsk 316 in the Ukraine, with 575,000 m.t., and Baskunchak on the Volga, 135x with 375,000 m.t., produced nearly 60 per cent of the total. Also of significance were the Urals, with 17 per cent, while the outputs of the Crimea, Kazakhstan, Central Asia, Eastern Siberia, and the Transcaucasus ranged from 7 per cent to 2 per cent of the national aggregate. Rock salt formed 35 per cent of all production; lake salt, 44 per cent; and evaporated-brine salt, 20 per cent.

Exports of salt in 1926 comprised 20,063 m.t. Thus internal con- [439]

x433 x/135 3/6 sumption was 1,620,000 m.t., or some 5.0 times Hypothetical Standard. Industrial consumption, however, was high: 295,000 m.t. or 140 per cent the American rate, when normalized for differences in total mineral consumption. It was utilized to produce 136,200 m.t. of soda ash (Na_2CO_3), 43,600 m.t. of caustic soda ($NaOH$), 20,000 m.t. of salt cake (Na_2SO_4), and 14,000 m.t. of sodium bicarbonate ($NaHCO_3$). Nevertheless, the demands of the glass, textile, fat, and petroleum-refining industries for sodium chemicals in that year was met only by 75–80 per cent. With high industrial demand and low output, the salt supply available for domestic use, food preservation, and livestock, barely 20 lb per capita, was correspondingly small (Geological Committee, 1927, pp. 653–674).

Salt production increased rapidly after 1926, reaching 2.3 million m.t. in 1927–28 and 3.2 million m.t. in 1930 and 1931. It then dropped to 2.6 million m.t. in 1932, rising again to 3.5 million m.t. in 1934 and 4.3 million m.t. in 1935, the last being well in excess of plan (TsUNKhU, 1936, p. 174). Furthermore, while the initial version of the Second Five-Year Plan called for outputs of 4.5 and 5.0 million m.t. in 1936 and 1937, respectively, the targets were later reduced to 4.0 and 3.2 million m.t. for these years (Ivanov and Alekseyevskii, 1935; State Planning Commission, 1937, pp. 104–105). It should be noted that salt production was marked by increasing concentration over the years 1927–1938. The two major deposits, Artemovsk and Baskunchak, raised their productions to 1,123,000 m.t. and 857,000 m.t., respectively, by 1930. In 1937–38, their outputs were even higher, 1,350,000 m.t. for Artemovsk and 1,037,000 m.t. for Baskunchak (1938), despite the over-all decline in salt production. Consequently, they were contributing some 75 per cent of all salt output at this time. In contrast, output of Iletsk rock salt in the Urals rose from 62,200 m.t. in 1926 to 202,000 m.t. in 1930 and then fell again to 128,000 m.t. in 1937. The evaporated salt industry, which had been especially important in the Urals and Eastern Siberia, declined from 20 per cent of national output in 1926 to less than 6 per cent in 1933 (Betekhtin, 1946, pp. 337–342; TsUNKhU, 1936, p. 174).

[439] Salt exports were never great during these years. They averaged 68,500 m.t. between 1927–28 and 1931, then rose gradually from 107,000 m.t. in 1932 to 177,000 m.t. in 1937 (Meisner, 1939, p. 93). The supply available domestically thus was very large, exceeding

computed expected demand by some 300,000 m.t. in 1930–31 and 433^x
by fully 1 million m.t. in 1935. Furthermore, the industrial consump- 135^x
tion of salt lagged greatly behind plan and fell sharply in relation to 316
the American rate of demand over this period. The Soviets anticipated a rise of industrial consumption from 680,000 m.t. in 1933 to 1,700,000 m.t. in 1937, contrasted to requirements at the American rate of some 500,000 and 1,600,000 m.t. for these same years. Actual industrial consumption can be deduced from soda ash output, which rose to 215,200 m.t. in 1927–28, 260,800 m.t. in 1930, 324,500 m.t. in 1933, 415,700 m.t. in 1935, and only 532,000 m.t. in 1938 (TsUNKhU 1936, p. 175; Lokshin, 1947, p. 819). The corresponding figures for total industrial consumption would have been about 2.2 times as great, judging from the 1926 ratio. The major causes for such underconsumption appear to have been the weak developments of glass and soap production. The former totaled 324,500 m.t. in 1927–28 and 566,900 in 1934, and then — judging by window-glass output — rose 76 per cent by 1936, only to drop rapidly thereafter, reaching a low of 88 per cent of the 1934 figure by 1940. (TsUNKhU, 1936, p. 180; 1939, p. 67; State Planning Commission, 1937, pp. 100–101; Bergson, *et al.*, 1949, p. 56.) The latter was 217,000 m.t. in 1928 and 495,200 m.t. in 1937, a rise of 2.25 times, or far less than average for Soviet industrial output generally (Ioffe, 1939, p. 195). Finally, salt was partially displaced in chemical use by sodium sulfate, as is discussed in the pertinent section. The consumption of salt domestically, for food preservation, and for livestock was stimulated by the rise of fish, bologna, and other food processing, but inhibited by the great losses of livestock resulting from collectivization (Jasny, 1949, p. 622). The net result was that great surpluses of salt accumulated. These may have been dissipated by the outset of World War, since Soviet consumption in, say, 1937 must have exceeded planned production by at least 300,000 m.t.

During World War II, loss of the Ukraine and the Crimea, and partial denial of access to Lake Baskunchak, unquestionably imposed a further reduction in Soviet salt production. It is doubtful whether output recovered to more than 2 million m.t. in 1944. Small supplies were also shipped via Lend Lease: 2.8 million lb in 1941, 1.2 million in 1943, and 649,000 in 1944 (Bureau of the Census, 1944, n.d., 1946*a*, 1946*b*). In all, the Russian wartime supplies of salt probably did not exceed Hypothetical Standard. A relatively

×433
×135
316

low output is also indicated for the postwar period, the 1950 goal being only 4,422,000 m.t. plus possibly 200,000 m.t. from the Kazakh S.S.R. Of this total, 1,930,000 m.t. was to come from the Ukraine (*Zakon o Pyatiletnom Plane,* 1946, *passim*). It is possible that the U.S.S.R. planned to augment this supply by imports from Eastern Europe.

An indication of the planned utilization pattern is given by the goal for soda ash production, 813,000 m.t. in 1950 (Korobov, 1946, p. 30). Total industrial use must have approximated 2.0 times as much (using the median between comparable ratios in the U.S.S.R., 1926, and the U. S., 1947). In consequence, 3.0 million m.t., or 33 lb per capita, would remain for domestic use, food preservation, and livestock.

Scattered data indicate that the soda ash goal was seriously underfulfilled. This supposition is strengthened by the known failure of the window-glass plan, which achieved only 65.6 million m^2 in 1950, opposed to a target of 80 million, and an actual achievement in 1936 of 87.9 million (Bergson, *et. al.,* 1949, p. 56; Central Statistical Administration, 1947–1951; TsUNKhU, 1939, p. 67). Claims in regard to soap production are also modest: 16 per cent over 1940, and probably not greater than achieved in 1937 (*Izvestiya,* 17 April 1951).

Satellite Salt Resources and Output. For the period 1927 through 1937, the total salt production of the Eastern European areas now controlled by the Soviet Union averaged some 2.8 million m.t. Of this, Eastern Germany produced 1,391,000 m.t. of rock salt plus about 400,000 m.t. of evaporated salt; Poland, 514,000 m.t.; Rumania, 316,000 m.t.; Czechoslovakia, 165,000 m.t.; and Bulgaria, 41,000 m.t. (Meisner, 1939, pp. 91–94). The net exportable salt surplus averaged 300,000 to 400,000 m.t. annually. Postwar data are incomplete, but show lowered output for Poland (347,000 m.t. in 1947), Bulgaria (22,900 m.t. in 1946), and especially Czechoslovakia (9,200 m.t. in 1946), the last being due partially to the loss of Ruthenia to the U.S.S.R. Rumania has shown a slight rise, to 314,500 m.t. in 1947 (*Minerals Yearbook,* 1947, pp. 1031–1032). East German output is not known, but is probably well below the prewar average. In all, it appears improbable that Eastern Europe currently can export much salt. Nevertheless, the deficiency indicated is temporary and readily remediable. The salt resources associated with the Stassfurt and allied carnallite deposits in Germany alone are virtually inex- 135x haustible (Merenkov and Muratov, 1942, pp. 189–190). 316

In the Far East, Korea averaged 159,000 m.t. of salt output 433x between 1928 and 1936; production totaled 268,000 m.t. in 1944 (Meisner, 1939, pp. 91–94; *Statistical Yearbook of the United Nations*, p. 161). Manchurian production reached 732,000 m.t. in 1933 and was rapidly rising. Unfortunately, fuller or later data are unavailable. In general, however, it is very likely that these regions can cover some of the perennial salt deficit of the Soviet Far East.

Salt Reserves and Deposits. The salt reserves of the U.S.S.R. ag- 135x gregate many billions of tons, and may be considered inexhaustible. It should be pointed out, however, that no significant deposits are yet known east of Lake Baikal. Furthermore, only the salt produced in the Ukraine, in the Urals, and at Usolye near Irkutsk uniformly comes up to Soviet minimum standards for salt consumption as food. These standards specify a minimum of 98 per cent NaCl, and maximum contents for other ingredients as follows: MgO, 0.18 per cent; CaO, 0.78 per cent; K_2O, 0.11 per cent; SO_3, 1.10 per cent; insoluble residue, 0.3 per cent; all nitrates and nitrites absent (Merenkov and Muratov, 1942, p. 168).

The salt deposits of the U.S.S.R. may be grouped into four categories: rock salt, salt springs and brine wells, seasonal salt lakes, and salt basins associated with marine inlets. The rock-salt deposits may be further subdivided into undisturbed sediments, laid down in ancient marine grabens, and salt domes. (See Ivanov and Alekseyevskii, 1935; Betekhtin, 1946, pp. 334–343; Merenkov and Muratov, 1942, pp. 175–198.) The bulk of Soviet rock-salt reserves can be ascribed to the first type, characterized by horizontal strata of salt often hundreds of meters thick, alternating with anhydrate, carnallite, and other formations. The large deposit of this character, Solikamsk in the Urals, must, however, be excluded, since the salt is too contaminated for commercial use. The reserves at Solikamsk have been guessed at 2 trillion tons. They are part of an enormous Permian (Kungur) formation extending west to Kazan' on the Volga and east to Shumkovo in the Urals. However, Shumkovo alone has present economic significance. Its measured reserves aggregate 179 million m.t. The salt is fair to good, with 97–98 per cent NaCl, 0.01–0.09 per cent $MgCl_2 + MgSO_4$, 0.8–1.4 per cent $CaSO_4$, and 0.67–1.6 per cent insoluble residue.

*135 In the Ukraine, the Artemovsk rock-salt deposit and associated salt springs at Slavyansk derive from Permian marine formations as at Shumkovo. Artemovsk salt is good, with an average composition of 97.8 per cent NaCl, 0.14 per cent $MgCl_2$, 1.2 per cent $CaSO_4$, 0.11 per cent $CaCl_2$, 0.42 per cent H_2O, and KCl and $MgSO_4$ lacking. The measured reserves alone are 27 billion m.t. (Merenkov and Muratov, 1942, pp. 186–188; Betekhtin, 1948, pp. 338–340). The Slavyansk springs produced 65,000 m.t. of vacuum-pan evaporated salt in 1933; it averaged 99.4 per cent NaCl, 0.16 per cent $MgCl_2 + MgSO_4$, 0.19 per cent $CaSO_4$, and 0.05 per cent insoluble residue. The reserves at Slavyansk are "large."

The two other significant rock-salt deposits, Tertiary Nakhichevan in the Transcaucasus and Jurassic Khodzhakan in Central Asia (Turkestan), are more recent, relatively small (54 and 125 million m.t. reserves, respectively), and of very poor quality. In 1933, Nakhichevan produced 34,000 m.t. of salt averaging 78–84 per cent NaCl, 0.2–0.7 per cent $MgCl_2 + MgSO_4$, 1.0–1.1 per cent $CaSO_4$, and 10.3–14.5 per cent insoluble residue.

The sole important salt dome presently developed in the Soviet Union is at Iletsk in the Urals. This Permian (?) deposit is large, with 1.5 billion m.t. of measured reserves, and has good salt: 96.9–99.8 per cent NaCl, 0.05–0.07 per cent $MgCl_2 + MgSO_4$, 0–2.0 per cent $CaSO_4$, and 0.24–0.40 per cent insoluble residue. Unfortunately, surface-water seepages through overlying Quaternary silts have made its operation increasingly difficult. Its erratic production history has already been noted.

In addition to Slavyansk, the wells of Usolye near Irkutsk in Eastern Siberia have been producers of vacuum-pan evaporated brine salt. At Usolye, the underlying formations are apparently Mesozoic. Although reserves at Usolye aggregate some 10 billion m.t., and the product is good (99.7 per cent NaCl, 0.07 per cent insoluble residue), production costs appear to be high. Output has seemingly remained close to its 1933 level of 20,000–26,000 m.t.

The seasonal lakes of the inner Asiatic drainage basins, which are in part replenished yearly, have very large reserves, but none except Lake Baskunchak in the Volga Economic Region combine size with fair quality. Baskunchak is underlaid by 35 meters of salt and clay, with a substratum of high-sulfurous mud. Usable salt is found only in the top 6 to 9 meters. These are augmented each spring by the flow of salt springs which deposit an average of 864,000 m.t. of NaCl. The total workable reserves have been estimated at 775 million m.t., but only a part of these, largely at the southern end of the lake, are usable for human or animal consumption. The solar-evaporated salt produced in 1933 ranged in content from 73 to 99.3 per cent NaCl, from 0.06 to 2.4 per cent $MgCl_2 + MgSO_4$, from 0.0 to 1.12 per cent $CaSO_4$, and from 0.03 to 6.22 per cent insoluble residue. 135x

Of the lakes in Turkestan, the largest producer in 1933 was Lake Tavalzhan near Pavlodar, with an output of 126,000 m.t. of washed, heat-evaporated salt, with good NaCl content (97–99 per cent), but heavily contaminated by magnesium salts (0.7–1.2 per cent). Its reserves total 53 million m.t. Next in importance was Lake Dzhaksy-klych near the Aral Sea, with a 1933 output of 41,000 m.t. and reserves of 96 million m.t. Its solar-evaporated salt ranges from 95–98.5 per cent NaCl, from 0.16 per cent to 1.39 per cent $MgCl_2 + MgSO_4$, from a trace to 3.6 per cent $CaSO_4$, and from 0.11 to 0.84 per cent insoluble residue. Lake Kuuli and the Dzhebel' Lakes in Central Asia produced 25,000 and 49,000 m.t. of solar-evaporated salt in 1933, respectively; the reserves of the first aggregate only 2 million m.t., and those of the second, 4 million m.t.

The Transcaucasian salt lake, Beyuk-Shor, produced 21,000 m.t. of very impure salt in 1933. This body of water is Russia's primary source of iodine.

Finally, the Soviets concentrate salt through solar evaporation from shallow basins in the inlets of the Sea of Azov and the Black Sea, particularly at Lake Sakskoye and Genichesk in the Crimea (Ukrainian Economic Region). These sources, while inexhaustible, have limited production capacities. The first produced 75,000 m.t. of good salt (97–99 per cent NaCl; 0.3–1.0 per cent $CaSO_4$) in 1933; the second, 63,000 m.t.

Natural Sodium Salts (Mirabilite and Thenardite). General. Of the natural sodium salts, only sodium sulfate has been significant in the U.S.S.R. The production and consumption of sodium sulfate or salt cake in Russia was very high in relation to American consumption as early as 1926. In that year, Soviet consumption totaled 28,000 m.t., nearly 11 per cent of the American[*] (Geological Com- 433x 135x

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[*] It must be remembered that Soviet mineral consumption as a whole was then running only 5 per cent of the American level.

X433 mittee, 1927, pp. 123–128). By 1935, it had reached 289,000 m.t.,
X135 exceeding contemporary American consumption (TsUNKhU, 1936, p. 174). Later statistics are unobtainable, but evidence on the continuing great importance of salt cake in Soviet industry is abundant (e.g., Makarov and Itkina, 1946, pp. 3, 26). This high rate of consumption is especially remarkable in view of the negligible development in Russia of the kraft-paper industry, which is the principal consumer of salt cake in the United States. However, a partial explanation exists in the increasing Soviet use, after 1930, of salt cake for the concurrent manufacture of soda ash (Na_2CO_3) and ammonium sulfate, through the Belopol'skii process which obviates the need for using deficient sulfuric acid (Vol'fkovich and Dubrovitskii, 1947, p. 1073). Salt cake has also substituted for soda ash, especially in the manufacture of glass (Druzhinin and Chelyadin, 1946). Finally, it is not unlikely that sodium sulfate is being used experimentally as a source of sulfuric acid. In all, while the available information on Soviet salt-cake utilization is scanty, the Russian pattern is clearly different from that of the United States.

TABLE 70

Soviet sources of salt cake

Product	*Output (thousands of metric tons)*			
	1926	*1927–28*	*1932*	*1935*
Mirabilite	63.9	101.7	419.5	469.8
Na_2SO_4 content	8.3	(14.2)	(54.5)	(61.1)
Thenardite	—	1.0	91.1	162.7
Synthetic Na_2SO_4	20.0	34.9	54.7	65.0
Total	28.3	(50.1)	(200.3)	(288.8)

Sources: Geological Committee, 1927, pp. 123–125; TsUNKhU 1936, p. 174; Betekhtin 1946, p. 334.

In contrast to most industrial countries, the U.S.S.R., after 1932, has derived the greater part of its salt cake from natural sources, especially Kara Bugaz Gol, formerly an eastern extension of the Caspian Sea. This is evident from Table 70. Basic reliance on natural salt cake continues today (Makarov and Itkina, 1946, pp. 3, 26).

No deposits of sodium sulfate have been reported for the Soviet-controlled areas in Eastern Europe or the Far East. The scales of

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synthetic production and of the total consumption of this chemical in these regions are also unknown.

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Sodium Sulfate Reserves and Deposits. The U.S.S.R. has enormous resources of natural sodium sulfate, abundant for self-sufficiency for the indefinite future. Most of these reserves derive from contemporary salt lakes in regions characterized by low precipitation, intense summer heat, and, consequently, high evaporation, coupled with severe winter cold. At low temperatures, especially in the presence of sodium chloride, mirabilite ($Na_2SO_4 \cdot 10H_2O$) is precipitated from the supersaturated salt solutions developed during the summer months by the solar evaporation of shallow natural or artificial basins. This mirabilite is washed ashore, as at Kara Bugaz Gol, or else recovered from under the water through holes cut in the ice, as at Selenga Lake (Druzhinin and Chelyadin, 1946). The recovered precipitate is then laid out on bare ground to weather during the coming summer. It decomposes into anhydrous sodium sulfate (thenardite) at temperatures above 90°F. The product marketed usually consists of 75 per cent or more mirabilite, and less than a quarter thenardite. In all, the technological level of this important industry was exceedingly primitive as late as 1946 (Makarov and Itkina, 1946).

The most important source of natural sodium sulfate in the U.S.S.R. is Kara Bugaz Gol (Turkestan). In 1940, this was a body of some 18,000 km^2 in area, with a maximum depth of 13 meters. It was connected with the Caspian by a channel 250 meters wide, through which about 18 billion m^3 of water flowed annually. Intense summer evaporation in Kara Bugaz Gol led to a salt concentration 20 times as high as in the Caspian and 6 times as high as in oceanic waters. Since the middle 1940's, moreover, the rapid drying up of the Caspian Sea has completely cut off Kara Bugaz Gol, so that the latter will probably dry out completely within a few years. The sodium sulfate content of Kara Bugaz Gol exceeds 500 million m.t., well in excess of forseeable Soviet needs (Betekhtin, 1946, p. 343). The main disadvantages of this deposit are its remoteness from consuming centers and the primitive technology employed (Makarov and Itkina, 1946, pp. 15–21).

Numerous smaller salt lakes producing sodium sulfate are scattered through Central Asia, Kazakhstan, and Siberia east to Lake Baikal. Among the more important commercially are Kolcha Lake

X,135 near Pavlodar in northern Kazakhstan, with reserves totaling 540,000 m.t. of sodium sulfate in 1927; Tuskol' Lake near Krasnoyarsk in Eastern Siberia, with 1.6 million m.t. of mirabilite; and Selenga Lake near Ulan-Ude, with 830,000 m.t. of mirabilite. All of these lakes are being exploited to supply local glass factories (Geological Committee, 1927, pp. 126–128; Druzhinin and Chelyadin, 1946; Pomus, 1937, p. 85).

Finally, the Uzun-su deposit in the Turkmen Republic (Turkestan) represents a formation of marine origin, of Cretaceous age. It contains numerous lenses of very pure thenardite (98.3–99.9 per cent Na_2SO_4) irregularly interspersed in mirabilite, gypsum, sodium chloride, and clays. The deposit covers about 8 km^2; the salt formations reach a thickness of 100 meters. Thus, while the measured thenardite reserves of this deposit are small, the quantities ultimately obtainable from it are undoubtedly great. This deposit is worked by open-pit mining (Merenkov and Muratov, 1942, pp. 196–197).

X433 *Sulfur and Pyrite. Summary.* Between 1926 and 1937, Soviet production
X/135 of sulfur-bearing minerals increased about tenfold. Then, during the war, it decreased by possibly one-third, since the loss
316 of corresponding sulfuric acid manufacturing capacity in the Ukraine and Leningrad must have sharply reduced demand. It is likely, however, that much of this loss was overcome before the end of World War II; output in 1950 is believed to have been approximately 50 per cent higher than in 1937, i.e., some 900,000 m.t. of sulfur content.

Although natural lump pyrite was by far the largest source of sulfur up to the mid-1930's, it has since been displaced by concentrates from Urals copper tailings and by coal brasses from Moscow Basin lignite. In addition, while statistics on natural sulfur output are lacking completely, it is certain that production has been adequate, since the middle 1930's, to cover indispensable demands. On the other hand, smelter-gas recovery has been extremely backward in the U.S.S.R., and remains but a minor source of sulfur chemicals.

X433 The Soviet Union, despite its sharp increases in sulfur minerals
X/135 output, and despite its relatively good consumption — 83 per cent
387 of Hypothetical Standard in 1926, 170 per cent in 1935, 115 per cent in 1937, and possibly 95 per cent in 1950 — has never been able to satisfy its needs. The primary reason for this fact is the great

demand for fertilizer occasioned by Russia's large cultivated area. 433x
Actually, the Soviets were able to meet the superphosphate goal set 135-x
for a smaller territory in the maximum variant of the *First* Five-Year 387
Plan only in 1950. The 1950 target, already 17 per cent less than
the one set in the Third Five-Year Plan for 1942, was underfulfilled.
Yet even then the Soviets have had to commit almost half their
sulfuric acid to the manufacture of fertilizers, a ratio virtually twice
the American. During World War II, however, explosives manu-
facture was easily the greatest consumer of sulfuric acid.

The over-all resources of sulfur-bearing minerals in the Soviet 433x
Union are well beyond foreseeable needs. The bulk are ascribed to 135-x
coal brasses; next in quantity appears to be native sulfur; finally, there are pyrite and other metallic sulfides. But the rate of coal-brass output is limited by that of Moscow lignite, while that of native sulfur is restricted by the severe technological problems and high costs of refining low-content, high-bitumen raw materials. Furthermore, Siberia and the Transcaucasus are deficient in developed sulfur resources. Consequently, the need for developing alternative sources of sulfur chemicals, such as sodium sulfate, has been real, above all in meeting the needs of the Baku petroleum and Western Siberian pulp industries.

None of the Soviet satellites except Northern Korea are known to be important producers of pyrite, although Rumania has appreciable reserves. Resources of native sulfur are completely unknown in these areas. Nevertheless, the Eastern European lignites can be developed as significant sources of sulfur chemicals, as can East German gypsum. Thus, while the immediate prospect for the European satellites is one of acute scarcity of sulfur, mitigated only by imports, especially from Scandinavia, possibilities exist for the ultimate solution of this problem.

Production, Imports, and Consumption of Sulfur. In 1926, the 433x
U.S.S.R. produced 105,244 m.t. of pyrite; of this, 81,358 m.t. derived 439
from the Urals, and 18,686 m.t. from small deposits in the Trans- 135-x
caucasus, while coal brasses from the Moscow region comprised 5,200 m.t. The actual consumption of pyrite in that year, however, exceeded output by 20 per cent, since 20,500 m.t. of old stocks were also used. Imports of pyrite were prohibited, in order to protect the domestic industry. In contrast, the entire supply of native sulfur, 8,593 m.t., or less than 40 per cent of the prerevoluntionary average came from abroad.

X433 X135 average, came from abroad. Thus the total sulfur content consumed in 1926 aggregated some 65,000 m.t., or 83 per cent of Hypothetical Standard. The principal use of sulfur was for the manufacture of 169,390 m.t. (monohydrate) of sulfuric acid, only 65 per cent of the then existing capacity. Marked deficiencies in supply were evident in the petroleum and paper industries; the scale of superphosphate production also was small. The principal reason for such an inadequate supply was the underproduction of pyrites; the recovery of sulfur in the manufacture of sulfuric acid was excellent, in excess of 90 per cent (Geological Committee, 1927, pp. 625–642).

TABLE 71

Soviet production and consumption of sulfur minerals, 1927–28 to 1937 (thousands of metric tons)

	1927–28	*1933*	*1935*	*1937*
Natural pyrite	175	415	516	(500)[c]
Concentrated copper tailings	—	216	369	(500)[c]
Coal brasses	(17.0)[b]	52	103	113[b]
Total pyrites	192	683	988	1113
Sulfur content[a]	87.3	307	444	501
H_2SO_4 from nonferrous smelter gases	10.6	34.2	79.7	(120)[d]
Sulfur content	3.3	10.3	24.1	(36)[d]
Natural sulfur				
Imported	(19.0)	3.1	—	—
Produced[e]	—	(30)	(50)	(80)
Total sulfur content consumed	110	(351)	(518)	(617)

[a] Calculated at 45 per cent of all pyrite.

[b] Calculated at 1.5 per cent of coal production in the Moscow Basin; cf. TsUNKhU 1936, p. 102, and Table 49.

[c] Estimated; total "pyrites," presumably natural and copper tailings, in 1938, 978,000 m.t. (Lokshin, 1947, p. 819); pyrite concentrate capacity of the Krasnoural'sk plant, 500,000 m.t. per year; cf. State Planning Commission (New Enterprise Plan, 1935, pp. 240–241).

[d] Calculated from increases in zinc, lead, and Urals copper output.

[e] Best guesses.

Source: TsUNKhU 1936, p. 174 (except as noted).

X433 X135 316 Pyrite production, excluding copper-concentration tailings and coal brasses, increased fivefold between 1926 and 1935 (see Table 71). As a result of such rapid depletion, and especially of long-continued and destructive subterranean fires at such important deposits as Kalata, the available reserves of natural pyrite became sharply restricted (State Planning Commission, 1936, I:130–131;

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Saakyan, 1937, pp. 9–10; Gerasimov, 1949). This situation was aggravated by the great difficulties met by the Soviets in mastering the new sulfuric acid manufacturing capacity installed during the First Five-Year Plan. The use of pyrite fines from copper tailings was particularly unsatisfactory (Vol'fkovich and Dubrovitskii, 1947, pp. 1077–1078). Thus the supply of sulfur minerals had to increase rapidly: pyrite from copper tailings, particularly at Krasnoural'sk (formerly Bogomolovsk) rose to 369,000 m.t. by 1935; coal-brass output in that year was 20 times that of 1926; and appreciable amounts of sulfuric acid were being recovered from nonferrous smelter gases. Yet the over-all recoveries of sulfuric acid fell so low — about 74 per cent in 1927–28, 60 per cent in 1933, and 64 per cent in 1935 — that the production of this fundamental chemical lagged far behind plan. The output of sulfuric acid in 1935 reached only two-thirds of the optimal 1932 goal of 1,450,000 m.t. (Table 72; State Planning Commission, 1929, II:254–257). The largest part of this output had to be devoted to meeting the great needs of agriculture, particularly for superphosphate; the next largest consumer was ferrous metallurgy. Supplies available to other industries remained far below demand (State Planning Commission, 1936, I:130–131). One bright spot, however, was the development of native-sulfur production in Central Asia and the Volga, which obviated the need for imports by 1935. Nevertheless, the sulfur industry was marked by extreme inefficiency between 1926 and 1935, which resulted in inability to meet goals despite large output of the raw materials — over 170 per cent of Hypothetical Standard in the latter year.

But 1936–1938 were years of radical improvement in Soviet technology, with great rises in the recovery of sulfuric acid (Vol'fkovich and Dubrovitskii, 1947). This made possible a 50 per cent increase in the production of the chemical with little increase in raw-materials output (Table 71). In addition, economies reaching 105,000 m.t. of sulfuric acid in 1938 were realized by the substitution of sodium sulfate for sulfuric acid in the manufacture of ammonium sulfate by the Belopol'skii process (Jasny, 1949, p. 495; Vol'fkovich and Dubrovitskii, 1947, pp. 1073–1074). Yet, the continued inadequacy of sulfuric acid production is shown by the failure of superphosphates output to rise above 75 per cent of capacity even in the peak year, 1938 (see the section on phosphate rock). Other details on this x433 important problem of sulfuric acid utilization are given in Table 72

x135 World War II decreased Soviet sources of sulfur minerals insignificantly. In fact, the increase of Moscow Basin lignite production to 20 million m.t. by 1945 alone may have led to a correlated growth in coal-brass output to some 300,000 m.t. However, plants producing fully 500,000–600,000 m.t. of sulfuric acid annually were lost at Leningrad and in the Ukraine. Adjustments of this reduced supply to growing military needs, which must have averaged at least 400,000–600,000 m.t. per year, were made primarily through drastic cuts in superphosphates output (as in Germany). Heavy damage to the Soviet steel industry also cut down its needs to less than half of the 1937 figure. Such internal compensations, plus the growth of capacity during the course of the war, made unnecessary significant Lend Lease shipments of sulfuric acid (Bureau of the Census, 1944, n.d.). The Soviet Union was entirely self-sufficient in native sulfur throughout the war.

TABLE 72

Estimated comparative utilization of sulfuric acid in the U.S.S.R., 1927–1937, and in the United States, 1937

	(thousands of metric tons)[a]				*(percentages of the total)*				
	1927–28	*1933*	*1935*	*1937*	*1927–28*	*1933*	*1935*	*1937*	*U.S. 1937*
Fertilizers	50.5[b]	254[b]	483	618[d]	24.0[b]	40.5[b]	48.6	41.2[d]	25.9
Iron and steel	42.0	69	126	177	20.0	11.0	12.7	11.8	12.8
Nonferrous metals[c]	7.2	20	(40)	62	3.4	3.2	4.0	4.1	7.2
Petroleum	23.4	45	54	61	11.1	7.2	5.4	4.1	12.8
Textiles	25.0	22	20	31	11.9	3.5	2.0	2.1	1.3
Cellulose	5.2	12	16	22	2.4	2.0	1.6	1.4	4.4
Miscellaneous	57.0	203	255	(420)	28.2	32.6	25.7	(35.3)	45.6
Total	210.5	627	994	(1500)	—	—	—	—	—

[a] Monohydrate (100 per cent H_2SO_4).

[b] Includes ammonium sulfate for 1927-28 and 1933.

[c] Also electroplating.

[d] 664,000 m.t. and about 41.5 per cent in 1938.

Sources: TsUNKhU 1936, p. 175; Jasny, 1949, p. 495; for textiles and cellulose, Ioffe, 1939, pp. 186, 189; *Minerals Yearbook, Review of 1940*, p. 1261.

Postwar production data for either sulfur minerals or sulfuric acid are lacking. Nevertheless, the former probably approximated 900,000 m.t. in 1950; the latter, possibly 2.2 million m.t. (monohydrate). This deduction arises from the following facts. Natural

pyrite, greatly depleted by heavy production and intermittent fires, 433 Y
had been largely displaced by concentrates from copper flotation, 135 X
coal brasses, and smelter gases in 1947 (cf. Vol'fkovich and Dubrovitskii, 1947, pp. 1059 ff). Certainly, 200,000 m.t. of pyrite seems a generous estimate. In copper tailings, the known major augmentation since 1946 has been the Blyava plant, expanded to a maximum capacity of some 450,000 m.t., judging from the deposit Cu:S ratio (cf. Gubkin, 1937*a*; State Planning Commission, 1936, II:420–421). The potential output of coal brasses from Moscow lignite has risen to 450,000 m.t. (see Chap. VI); the sulfur content of nonferrous smelter gases, to about 50,000 m.t. The Soviet output of natural sulfur is purely conjectural, though it is clear that this commodity is too scarce and too expensive for use in such secondary purposes as the output of sulfuric acid. That the latter was none too plentiful is indicated by the failure of the superphosphates plan. On the other hand, a lower limit of 2.0 to 2.2 million m.t. of 100 per cent H_2SO_4 can be set for 1950 output by reviewing the following fixed demands: fertilizers (superphosphate only), 1,175,000 m.t.; iron and steel, 250,000 m.t.; nonferrous metallurgy 190,000 m.t.; and petroleum, 90,000 m.t.; leaving only 295,000–495,000 m.t. for all other purposes.

Satellite Sulfur Resources and Production. Of the satellite countries, North Korea alone has had a rapidly growing production of pyrite in recent years; its reserves are unknown. Poland's output, including that of former German territory, is almost entirely a by-product of its lead-zinc smelters. Before the war it covered 56 per cent of the country's consumption (Friedensburg, 1938, p. 368). Czechoslovakia normally imports 90 per cent of its consumption (*ibid.*, p. 429). In Eastern Europe, Rumania alone has fair-sized, largely unexploited pyrite resources. As a whole, the postwar sulfuric acid production of the European satellites does not exceed three-fourths of the prewar levels; the raw materials for even this lowered output came, to a substantial degree, from imports, especially Scandinavian. One may note Finland's growing pyrite output, largely a by-product of the Outokumpo copper mine — over 152,000 m.t. in 1947, compared to 103,000 m.t. in 1938 (cf. Bryk *et al.*, 1947; *Mineral Trade Notes,* vol. 26, no. 4, pp. 5–8, April 1948). Finally, it should be remembered that considerable easing of the Eastern European pyrite deficiency can ultimately be gained by x[433] x135

the substitution of coal brasses and gypsum as sources of sulfuric acid (Table 73).

Sulfur Reserves and Deposits. Excluding sodium sulfate and gypsum, the greatest Soviet resources of sulfur minerals are contained as coal brasses in the Moscow Basin lignites of Central and Northwest Russia. These average 1.6 per cent of the lignite by weight, and aggregate 200 million m.t.,, running 46 per cent sulfur content (Geological Committee, 1927, p. 638; Chap. VI). Also, the reserves of native sulfur total 60 million m.t. or more. In 1927, the total Soviet reserves of pyrite and allied sulfides were estimated at 51.2 million m.t. (XIV Internat. Geol. Cong., I:47, 57), though only half were workable (Geological Committee, 1927, pp. 631–642). Of the remainder, another half at least has been mined out or destroyed by fires; however, this depletion has been more than offset by the discovery of Blyava in the southern Urals, with some 16 million m.t. of pyrite reserves. Sulfide-bearing copper tailings amounted to 23.8 million m.t. in 1927, but have since been substantially depleted. To summarize, Soviet reserves of sulfur minerals far exceed Hypothetical Standard needs to 1970, 47.5 million m.t. of sulfur

TABLE 73

Pyrite and sulfuric acid output in the satellites

		Pyrite			*H_2SO_4*
Country	*Year*	*Output* *(10^3 m.t.)*	*S Content* *(10^3 m.t.)*	*Reserves* *(10^6 m.t.)*	*(10^3 m.t. of 100% H_2SO_4)*
E. Germany	1936	8.4	4.0	?	442
Poland	1937–38	92.2	36.9	Small	181
(Incl. E. Germany)	1947–49	39.7	18.0	Small	276
Czechoslovakia	1937–38	?	?	Small	166
	1946–48	8.0	2.9	?	215
Rumania	1937–38	80.0	?	10.7	39
	1947	?	?	10.7	26
N. Korea	1938	133	53	Large?	?
	1944	246	98	Large?	?
Finland	1938	103.0	44.3	4.0	?
	1947	152+	?	4.0	?

Sources: Minerals Yearbook, 1947, p. 1135; *Statistical Yearbook of the United Nations*, 1948, p. 164; Office of Military Government, Germany, 1949, pp. 282, 309; XIV International Geological Congress, 1927, I:47.

content. They are found largely in European Russia and Turkestan; the Transcaucasus and Siberia lack significant sulfur resources.

Native sulfur is restricted to Turkestan and the Volga Region. At Gaurdak, in the Turkmen S.S.R., sulfur-bearing lenses and layers are developed in Upper Jurassic limestones. The total thickness of the productive horizons is 60 to 90 meters; sulfur content ranges from 5 to 80 per cent, averaging 12 to 15 per cent. Bituminous admixtures occur in significant quantities and undoubtedly hamper the recovery of high-grade sulfur. In 1931, measured reserves aggregated 10 million m.t.; total reserves, over an area of 30 km^2, were possibly 500 million m.t. of ore (Merenkov and Muratov, 1942, pp. 212–213; Kashintsev, 1933, p. 113). The Shikh deposit, also in the Turkmen S.S.R., is much smaller but better. The ore, a fine quartz sand cemented together with sulfur, averages 50 per cent sulfur content. In 1926, total reserves were estimated at 1.2 million m.t. of sulfur content (Geological Committtee, 1927, pp. 629–630). In the Fergana Valley, the Shorsu deposit was first thought to be small (25,000 m.t. reserves, as of 1927), but larger bodies were seemingly found later. In 1946, the deposit was, to use Betekhtin's words (1946, p. 323) being subjected to "intense exploitation." The deposit is Eocene, and associated with karsts formed in earlier limestone. The productive horizons extend to a depth of 50 meters; the upper oxidized horizons, however, are the most important, since there weathering has concentrated the sulfur at exposed levels into dense caps. The sulfur content of the ore ranges from 15 to 24 per cent (Geological Committee, 1927, p. 630).

In the Volga Region, the principal deposits are Vodinsk and Alekseyevskoye. The two productive horizons at Vodinsk, the larger deposit, lie at depths of 8 to 16 and 35 to 40 meters, respectively. The veins of ore, developed in Permian limestones, range from 0.6 to 3.5 meters in thickness, and 7 to 20 per cent in sulfur content, which takes the form of disseminated crystals, often of considerable size, and sometimes of conglomerations reaching 2.5 meters in diameter. The lower horizon is heavily infiltrated with bitumen. Alekseyevskoye resembles Vodinsk, but has a lower average sulfur content, 11 per cent. According to Betekhtin (1946, pp. 322–323), these two deposits aggregate "millions" of tons in reserves; Bykhover and Rozin (1947, p. 266) state that they comprise 80 per cent of x/135 Soviet total sulfur reserves, but only 36 per cent of the measured reserves, and 12 to 13 per cent of the output.

Soviet pyrite reserves, both natural and copper by-product, appear to be associated solely with Urals copper deposits (Chap. IV, Sec. 3). The most significant deposits are Krasnoural'sk, with 10.6–13.3 million m.t. of iron pyrite plus 6.2 million m.t. of copper by-product pyrite in 1927; Degtyarka, with 15.0–26.0 million m.t. of pyrite as of the same year; Kalata, with over 1.46 million m.t. in 1927, but subsequently damaged by great fires; and Blyava (XIV Int. Geol. Congress, I:376–377; Geological Committee, 1927, p. 635 ff). The reserves of the last are not exactly known but they run some 13 to 16 million m.t. of pyrite equivalent (Gubkin, 1937*a*; Balzak, Vasyutin, and Feigin, 1949, p. 259). The remainder of the pyrite reserves ascribed to the U.S.S.R. in the reports of XIV Geological Congress, especially those in Siberia and the Transcaucasus, must be discounted. They appear to be far too lean to concentrate mechanically, or else too small to have much significance. On the other hand, the recovery of sulfur chemicals from the smelting of not only copper and lead-zinc ores, but also nickel and other sulfides, can be a factor of increasing importance.

4. *Miscellaneous Nonmetallics*

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Barite and Witherite: Summary. Low production and consumption have long characterized the Soviet position in barite and witherite. Yet, although specialists realized that this was unsatisfactory, the development of deposits and of barite technology remained haphazard. Also, imports were negligible; the Soviet Union, in fact, exported 2,850 m.t. of its meager output in 1935. By 1946, the deleterious effects of inadequate barite supply for the petroleum, paper, paint, and atomic-energy industries were realized. In addition, larger German production passed under Soviet control. Thus, barite supplies since 1947 have probably equaled the Hypothetical Standard demands of the U.S.S.R. But, if this is so, at least two-thirds of these supplies are imported; the domestic barite resources of the Soviet Union can become adequate to supply Hypothetical Standard consumption to 1970 only if the most optimistic inferred reserves become realities.

Production, Foreign Trade, and Consumption of Barite, 1926–1946: In 1925–26, the U.S.S.R. produced 14,389 m.t. of barite, of

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which 50 per cent came from the Georgian S.S.R., 30 per cent from the Urals, and 10 per cent from Azerbaidzhan. This production marked a great increase over the output of 1913, 1,853 m.t., but the accompanying drop in imports, from 17,949 m.t. to 153 m.t., led to a fall in visible consumption from 19,802 m.t. to 14,542 m.t. This supply, though exceeding Hypothetical Standard by 21 per cent, was far from adequate for Russia's relatively large petroleum industry. It satisfied only 55 per cent of Soviet estimated requirements, leading to an "unquestioned starvation" for barite and witherite (Geological Committee, 1927, pp. 75–89).

By 1937, production had risen to 70,000 m.t., of which 54 per cent came from Georgia, and the bulk of the remainder from new mines near Salair in Western Siberia; the Urals mines and the Arpaklen group in Central Asia had been retired from production as being economically unfeasible (Betekhtin *et al.*, 1946, pp. 316–318; Lyubimov, 1946*a*, p. 7). It is noteworthy that 1937 output exceeded the plan for that year (66,500 m.t.); the inadequacy of the Second Five-Year Plan for barite (cf. Dvorshchan and Lyubimov, 1935), however, is visible at a glance. Forty-seven per cent of the output was to be consumed as $BaCl_2$ in insecticides alone. Hypothetical Standard consumption for the U.S.S.R. in 1937 would have been 82,500 m.t.

At the very outbreak of World War II, possibly in 1940, production totaled, according to Lyubimov (1946*a*), about 100,000 m.t., of which 50 to 60 per cent now came from Salair. The petroleum industry consumed 70 to 80 per cent of this total; the barite furnished was markedly substandard, the Belovo concentration plant for the Salair mines yielding $BaSO_4$ with specific gravities of 4.1–4.16, while the product from Chovdar (Azerbaidzhan) had even lower specific gravities of 3.7–3.8, against minimum specifications of 4.2. Most of the remainder of the barite output was consumed by the two lithopone (pigment) plants, at Kutaisi in Georgia and at Leningrad. Small quantities went to rubber manufacture and some chemical uses, but none was available for paper, glassmaking, or other industrial purposes.

Despite the desperate need of the Soviet Union for increased rather than diminished petroleum output during World War II, no efforts were apparently made to increase barite production, nor was any barite shipped via Lend Lease. The resulting shortage of

x433 barite was an important factor contributing to the decline of Baku
x135 petroleum production during World War II; attempted Soviet
316 substitution of magnetite sands for barite in drilling muds failed (Mkrtchyan, 1947). In 1946, Lyubimov characterized the Soviet barite situation as being "exceptionally tight."

Satellite Barite Supplies. To the good fortune of the Soviet Union, however, World War II gave it control over half of the barite resources of Germany, the world's largest producer prior to World War II. The Soviet Zone of Germany is stated to have yielded 267,984 m.t. of $BaSO_4$ in 1942. Such an output, plus a continuation of Soviet production at the 1937–1940 level (70,000–100,000 m.t.), plus modest supplies from North Korea (5,640 m.t. produced in 1944), would fully cover the war or peacetime Hypothetical Standard demands of the entire Soviet sphere in 1950 (*Mineral Trade Notes,* vol. 23, no. 2, p. 48, August 1946; *Minerals Yearbook*, 1946, page 166).

x135 *Barite Reserves and Deposits.* By optimistic guesswork, total Soviet barite and witherite reserves in 1935 amounted to 18.0–23.0 million m.t. (Dvorshchan and Lyubimov, 1935). Up to 1946, these reserves had been augmented by clearly minor finds in Central Kazakhstan, and reduced by the mining of some 1.1 million m.t. Such total reserves, if verified, would be ample to cover Soviet Hypothetical Standard needs to 1970, 12,200,000 m.t.

Unluckily, 10 million m.t. of these reserves are pure geological inference concerning an isolated deposit of the Kazakhstan desert (Kara-gaili). Another 1,642,000 m.t. are comprised in indication and inferences concerning another desert deposit (Arpaklen). This one had been mined briefly in the 1930's, but was later abandoned as being too difficult to operate and possessing too few *proved* reserves. Finally, still another 1,193,000 m.t. (of which 500,000 m.t. were classified as operating or A_1) marked the resources of Urals deposits which were workable only for lump barite (25 per cent recovery) but defied Soviet scientists in yielding the 35–40 per cent of $BaSO_4$ locked in their ferruginous, clayey ores. With these corrections, only some 4 to 9 million m.t. of reasonably firm reserves remained as of January 1, 1948. Witherite ($BaCO_3$) reserves have always been insignificant, being assessed at 10,550 m.t. in 1935 (entirely at Arpaklen).

Soviet barite and witherite deposits are located in the Trans-

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caucasus, Western Siberia, Eastern Siberia, Turkestan, and the Urals (Lyubimov, 1946*a*; Glembotskii *et al.*, 1943; Merenkov and Muratov, 1942, pp. 130–139). The greatest *firm* reserves (2.8 million m.t. total in 1935; at least 2.5 million m.t. in 1948) and the greatest likelihood of new discoveries appertain to the Georgian S.S.R. in the Transcaucasus. In the valleys of the Rion and Kvirila Rivers, northeast of Kutaisi, are over 100 veins of 96 to 98 per cent, even 99.33 per cent, $BaSO_4$, some reaching lengths of several kilometers and thicknesses up to 1 meter. All apparently derive from hydrothermal deposition in the tectonic cracks of a Middle-Jurassic tuff-porphyry formation. The same origin may be ascribed to the small barite deposit at Chovdar (Gandzha) in Azerbaidzhan, which is important because of its proximity to the oil fields. However, in quality the Chovdar barite appears to deteriorate with depth, being increasingly mixed with quartz and calcite at lower horizons. Its operating (A_2) reserves totaled 83,200 m.t. in 1935.

In Western Siberia, Salair, near the Kuznetsk Basin, carries 35 to 40 per cent $BaSO_4$ in tailings from zinc and gold mining. With optimal processing, 80 to 85 per cent of this barium sulfate can be recovered, with a 96 to 98 per cent purity including low iron and silica (Dvorshchan and Lyubimov, 1935). In reality, the barite produced has been of lower quality, but recoveries have been good; initially estimated reserves have been augmented. This deposit, credited with 700,000–800,000 m.t. of reserves in 1935, has been producing 50,000 m.t. annually since then. Yet, in 1946 it presented no threat of exhaustion (Lyubimov, 1946*a*). On the other hand, the Zmeinogorsk deposit, credited with 779,600 m.t. of reserves in 1935, appeared to be "basically exhausted" in 1946.

Near the upper reaches of the Yenisei, in Eastern Siberia, is the Chapsor-Dag or Askyz group of deposits, with 64,400 m.t. of measured plus 523,300 m.t. of indicated reserves of good barite (82–92 per cent $BaSO_4$, 0–2.6 per cent SiO_2, 0–0.56 per cent $Al_2O_3 + Fe_3O_4$). Their inaccessibility has thus far limited output, but completion of the Kuznetsk Basin–Abakan railroad would solve that problem (Onufriyev, 1946).

In Turkestan, near Arpaklen in the Turkmen S.S.R., more than 50 ore bodies had been found by 1935. They apparently represent veins of 94.8 to 99.4 per cent $BaSO_4$, with some lenses of witherite at Arpaklen proper averaging 72 per cent $BaCO_3$. The size of the

X 135 reserves was unknown as late as 1946; Dvorshchan and Lyubimov (1935) had guessed 2 million m.t. and Kazentsev (1935), 7 million. Equally conjectural are the prospects of the Kara-gaili deposit in Eastern Kazakhstan, which consists of three lenses, 80, 220, and 350 meters long and up to 160 meters thick. The inferred reserves are 10 million m.t. The Arpaklen and Kara-gaili deposits may be of sedimentary origin, unlike all other Soviet barite deposits, which are clearly of hydrothermal type.

Finally, passing mention may be made of one presently submarginal deposit. The Medvedevka site in the Urals consists primarily of a vein over 2.25 km long with a maximum thickness of 8.5 m. at depths of 100–140 meters. The average barite content of the ore is 37.6 per cent, largely disseminated as fine crystals in clay; 21.5 per cent Fe_3O_4 and quartz are adulterants. Until the early 1930's this deposit was worked by open-pit mining and hand selection of lump barite (25 per cent recovery). Laboratory experiments showed the possibilities of mechanical concentration; of the 1,193,700 m.t. recorded here in 1935, 700,000–730,000 m.t. represented the practical recovery, it was believed (Kazentsev, 1935). This was not confirmed in practice.

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Bromine. General. Strong indirect evidence indicates that substantial Soviet bromine output began only during World War II, but reached at least 9,000 m.t. in 1944. This war-built capacity, plus acquisitions in the Soviet zone of Germany, certainly exceed Hypothetical Standard peacetime requirements for the entire Soviet sphere, and wartime demands for the U.S.S.R. alone, as of 1950. Postwar specifications for both motor-vehicle and aviation gasolines show a lavish use of antiknock fluid; hence, of bromine. Russian domestic resources of bromine, and those of Eastern Germany, far exceed any foreseeable demand.

Direct information on Soviet bromine production is very scanty. In 1926, output totaled but 3.3 m.t. In addition, 72 m.t. were imported, to give a total supply considerably exceeding the Hypothetical Standard consumption of 38 m.t. (Geological Committee, 1927, p. 93). By 1932, output had increased to 200 m.t., according to Meisner (1939, pp. 103–104), and to 435 m.t. in 1935 (TsUNKhU, 1936, p. 178), but appears to have remained at under 1,000 m.t. as late as 1941. Although 1937 supply was very low compared to a Hypothetical Standard peacetime demand of 2,850 m.t., imports were not evident, nor were indications of plans for major expansion of output. Soviet motor vehicles in 1937 ran on unleaded gasoline, while the Red air force was not yet in a period of frantic expansion.

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The following deductions on the growth of Soviet bromine output after 1941 rest on study of Lend Lease imports of aviation gasoline and bromine during World War II, coupled with computations of the rise in Soviet air operations over the same period. In general, we estimate that the consumption of aviation gasoline in the U.S.S.R. developed as follows (in thousands of barrels): 1941, 2,700; 1942, 8,800; 1943, 13,500; 1944, 20,800. Of this consumption, the following was supplied by imports of finished gasoline (again in thousands of barrels): 1941, 1,700; 1942, 2,108; 1943, 3,050; 1944, 5,155 (Bureau of the Census, 1944, n.d. 1946*a,* 1946*b*). The following domestic production is left: 1941, 1,000; 1942, 6,692; 1943, 10,450; 1944, 15,645. For the manufacture of aviation gasoline, bromine at the rate of 1 lb per 1.9 barrels is required. The bulk of this was supplied by the United States until 1944, as is shown in Table 74. Thus the assumption of important Soviet bromine production, beginning in 1944, is inescapable.

TABLE 74

Estimated bromine requirements and supply in the U.S.S.R., 1941–1944 (metric tons)

	1941	*1942*	*1943*	*1944*
Requirements				
For aviation gasoline	525	3,520	5,500	7,920
For motor vehicles and all other[a]	105	700	1,100	1,580
Supply				
Imports	0[b]	3,006[b]	4,976	266
Estimated output	630	1,220	1,620	9,240

[a] 20 per cent added to aviation-gasoline demand.
[b] 1941 imports ascribed to 1942 aviation-gasoline utilization.
Source: Bureau of the Census, 1944, n.d., 1946 *a*, 1946 *b*; see Appendix II, Table 97.

After the war, the U.S.S.R. acquired control of 78 per cent of the German potash industry, which produced bromine as a by-product. In the period 1927–1937, the peak of German production had been 2,197 m.t. (cf. Meisner, 1939, pp. 103–104; Friedensburg, 1938, pp. 120–121); details of subsequent expansion or war damages are

x433 unobtainable. But it is clear that the bromine-producing capacity
x135 of the Soviet sphere as a whole approximates fully 11,500 m.t. Finally, bromine production has been maintained at a substantial level since the war. Gasoline output in the U.S.S.R. has risen from about 6 million m.t. (51 million bbl) in 1947 to some 8.7 million m.t. in 1950, nearly double the wartime peak (Chapter VI; Shimkin, 1950*a*). Despite such increases, the allowances for antiknock fluid in Soviet gasolines have continued to be very heavy: 1.5 ml/kg for motor-vehicle gasolines other than those used by prewar-model trucks (GAZ-AA and ZIS-5); 3.3 to 4.0 ml/kg, for aviation gasolines (see Table 63).

x135 *Bromine Reserves and Deposits.* The only known sources of large quantities of bromine in the U.S.S.R. are the twin deposits of Solikamsk and Berezniki, on the western flank of the Urals (see also the sections on magnesium salts and on salt). Here bromine is found as an isomorphous admixture to carnallite, transforming it to brom-carnallite: $K(Cl,Br) \cdot Mg(Cl,Br)_2 \cdot 6H_2O$. The proportion of bromine in Solikamsk carnallites averages 0.15 to 0.20 per cent, reaching a maximum of 0.25 to 0.30 per cent at depths of 103 to 126 meters, and a minimum of 0.07 to 0.15 per cent in the lower (silvinite) horizon. Reserves aggregate over 100 million m.t. of bromine (Betekhtin, 1946, pp. 334–343; Merenkov and Muratov, 1942, pp. 166–167, 171, 188–195).

x135 *Corundum and Emery. General.* The Soviet Union has long been
x433 a major producer of natural corundum and emery. Nevertheless, the
439 low quality produced and also the inadequate development of artificial-abrasive output (carborundum, aluminum oxide, steel shot, etc.) forced significant dependence upon imported abrasives, especially during World War II. Data on total abrasives consumption are lacking, but the level appears always to have been low. At the present time, Soviet emery reserves are fair to large, but corundum is on the verge of exhaustion. No record of corundum or emery resources has been found for the satellite regions.

In 1926, the U.S.S.R. produced 898 m.t. of corundum plus 6,398 m.t. of emery. Furthermore, a few tons of corundum were manufactured, and 93 m.t. of ground emery were imported (Geological Committee, 1927, pp. 327–334). During the following decade, output grew. In 1935, refined corundum and emery production was 8,400 m.t.; in 1936, 13,500 m.t. (State Planning Commission, 1937,

pp. 90 ff). The planned output for 1937 was 14,000 m.t., according 135x
to this source; raw corundum and emery production in that year 433x
amounted to 14,137 m.t. and 15,101 m.t., respectively (Betekhtin, 439
194[illegible], p. 272), indicating a recovery of finished products of some 50 per cent. During this entire period, imports of abrasives continued, although on a diminishing scale: 3,400 m.t. in 1931; 1,000 m.t. in 1935, 1,800 m.t. in 1936; 1,200 m.t. in 1937 (Bakulin and Mishustin, 1939).

The consumption of natural corundum and emery in the Soviet Union between 1926 and 1937 far exceeded Hypothetical Standard requirements, namely, 445 m.t. for 1926 and 1,900 m.t. for 1937. This fact indicates, however, not a special development of precision industries such as optics or high-grade machinery, but a pronounced lag in artificial-abrasives manufacture. The Second Five-Year Plan goal of 40,000 m.t. of carborundum in 1937 (Shabynin, Oparin, and Karmazin, 1935, esp. pp. 3, 54) was clearly not even approached, while Shul'kin's (1940) minute breakdown of Soviet ferrous-metals output and consumption in 1938 shows no utilization of abrasive steel shot. It should be mentioned that Koifman's report in 1939 characterized the abrasives industry of the Soviet Union as both quantitatively and qualitatively backward, failing to meet industrial requirements especially for the finer grades of abrasive powders.

During World War II, imports of abrasives rose steadily: 1,381,000 lb in 1941; 4,845,000 lb in 1942; 17,702,000 lb in 1943; and 24,917,000 lb in 1944 (Bureau of the Census, 1944, n.d., 1946*a*, 1946*b*). Although part of this demand may be explained by reduced supplies because of damage to the Leningrad (Ilich) abrasives plant, it is largely attributable to the growth in Soviet industrial standards occasioned by military necessity.

Postwar data on Soviet abrasives output are totally lacking. It is only known that Semiz Bug in Kazakhstan, the primary Soviet source of corundum, is now nearly exhausted (cf. Betekhtin, 1946, pp. 272, 278).

Corundum and Emery Reserves and Deposits. According to 135x
Betekhtin (1946, p. 272), total Soviet reserves at the end of World War II aggregated "a few thousand tons" of corundum and about 100,000 m.t. of emery. For corundum, this indicates the exhaustion of Semiz Bug in Turkestan, and sharp downward reassessment of reserves at Aktash (also in Turkestan) and Chainyt in Eastern

x/135 Siberia, from Gubkin's (1938*d*) figures of 112,000 and 41,000 m.t., respectively. Kholmyanskii's paper (1946) confirms this supposition for Aktash.

For emery, Betekhtin's figure appears low; it apparently excludes newly discovered Obukhovo near the Kuznetsk Basin in Western Siberia (Stolyar, 1945). The ore body there is a vein 4 to 6 meters thick, which has been followed for 200 meters and may extend much farther. Stolyar hopefully guessed the reserves at "millions" of tons. Samplings indicate a good ore: 53.5–69 per cent Al_2O_3, 3.5–15.4 per cent SiO_2, 9.0–16.0 per cent Fe_2O_3, and 2.6–3.3 per cent TiO_2. Other Soviet emery deposits include the Irtyash-Kyzyltyash-Techenskii group in the central Urals, the sole producer in 1937. At that time, its total reserves were 173,400 m.t. of ore, running 33 to 49 per cent corundum content. Finally, Poldnevaya in the northern Urals has 47,300 m.t. of inferred reserves, varying in composition from 0 to 60 per cent corundum. In all, Soviet long-term self-sufficiency in emery is not unlikely.

Geologically, Soviet corundum and emery deposits are heterogeneous. At least four types are represented: at Semiz Bug and Aktash, the deposits are magmatic segregations in granitic intrusions, with subsequent partial concentration through weathering. Chainyt was formed through the metamorphosis and weathering of Pre-Cambrian clays (see also, for these deposits, the section on andalusite); the Irtyash group and probably Obukhovo illustrate metasomatic alterations in limestones, subsequent to pegmatitic intrusions; Poldnevaya shows comparable changes in ultrabasic rocks (Bateman, 1942, p. 811; Betekhtin, 1946, pp. 270–279; Gubkin, 1938*d*; Merenkov and Muratov, 1942, pp. 49–58; Ozerov, 1933; Rusakov and Nakovnik, 1932; Shabynin, Oparin, and Karmazin, 1935; Stolyar, 1945).

k/135 *Diamonds.* The Soviet sphere lacks significant diamond resources.
k/33 Before World War II, Soviet industrial-diamond consumption com-
439 pared in scale with the American of 1926 and earlier (see Appendix I). Imports, averaging 23,100 metric carats annually between 1929 and 1936 (Bakulin and Mishustin, 1939), constituted the entire supply. But during World War II, diamond imports and consumption rose rapidly. Between October 1, 1941 and March 31, 1946, the United Kingdom alone sent the Soviet Union £1,424,000 worth of industrial diamonds (*Mineral Trade Notes*, vol. 22, no. 6, p. 49, June

1946). With an estimated price of two carats per British pound, the 135-x
physical quantity shipped approximated 2.8 million carats, an annual 433x
average of 620,000, or some 5 per cent of the peak American wartime 457
rate of industrial-diamond consumption. It is more likely, however, that the great bulk of these diamonds were stockpiled, forming the principal source of postwar diamond supply. According to reliable private information, diamonds still remain a primary Soviet import requirement from Great Britain.

Up to 1922–1925, somewhat less than 300 diamonds had ever been found in Russia (Fersman, 1922–1925, esp. I:11–25). The sole producing area is the central Urals, especially the placers of Krestovozdvizhinskii Priyisk, which yielded 42 stones aggregating 12 carats in 1938 and may give a minute but reasonably continuous output (Volosyuk, 1941). The probable primary source of the diamonds rests in highly metamorphosed series of early Paleozoic and possibly Pre-Cambrian age immediately east of the placers (Volin, 1938; Avarin and Shafranovskii, 1939).

Fluorspar. Summary. Production of fluorspar in the Soviet Union 433x
began in 1922. By 1926, self-sufficiency had been achieved on a very 135-x
low consumption level. The following decade witnessed sharp rises 316
in fluorspar output, and a marked reduction in the gap between supply and demand (both Hypothetical Standard and by Soviet computations). During World War II, loss of half of Soviet steel production eased requirements for fluorspar supply, so that Lend Lease imports were unnecessary. Since the war, the availability of large fluorspar production from Eastern Germany and North Korea not only has led to ensured self-sufficiency for the entire Soviet sphere, but also may make exports possible. Soviet fluorspar resources more than cover Hypothetical Standard requirements to 1970.

Production and Consumption of Fluorspar. In 1926, the Soviet Union produced only 3,765 m.t. of fluorspar, largely from two mines in the Transbaikal: Abagaitui (2,814 m.t.) and Kalangui (888 m.t.). Consumption was even lower, only 1,476 m.t.; of this, 49.6 per cent went to metallurgy, 44.9 per cent to the chemical industries, 2.2 per cent to the manufacture of silicates, and the rest for miscellaneous uses (Geological Committee, 1927, pp. 520–521). Considering that the Soviet steel output in 1926 was 2.9 million m.t. (*ibid.*, p. 207) and the normal input of fluorspar per metric ton of steel is 3 kg, it

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is clear that effective purification and crystalline-structure control of steel was not being practiced at that time. Hypothetical Standard consumption of fluorspar would have been 8,500 m.t.

A significant increase in Soviet fluorspar output began in 1929–30, but demand far exceeded supplies up to 1935. Thus in 1933, according to Luchitskii (1937, p. 314), industrial requests for fluorspar totaled over 50,000 m.t. against supplies of 10,450 m.t. (Production in that year was 19,388 m.t., cf. Luchitskii, p. 311; evidently shipping losses and delays accounted for the difference.)

In 1935 and 1936, production finally approached demand, as a result of the continued development of the Transbaikal mines, especially Kalangui, and of the opening of new mines in Central Asia (Aurakhmat) and North Russia (Amderma). The output in 1935 totaled 47,859 m.t., of which 17,800 m.t. came from Kalangui, 9,300 m.t. from Abagaitui, 9,000 m.t. from other mines in the Transbaikal, 3,000 m.t. from Aurakhmat, and 8,759 m.t. from Amderma. Soviet production in 1936 totaled 58,095 m.t., including 15,195 m.t. from Amderma (Luchitskii, 1937, p. 311; State Planning Commission, 1937, p. 90 ff; Kisel'gof, 1937). Soviet fluorspar requirements for these years have been computed by Yakubovits (1936, p. 7), whose estimates vary from American practice in his enormous allowances for insecticides (Table 75). Soviet Hypothetical Standard fluorspar consumption in 1937 would have been 46,500 m.t. but actual needs would have totaled some 60,000–65,000 m.t. because of Russia's relatively large steel industry.

TABLE 75

Soviet fluorspar requirements, 1933–1937 (thousands of metric tons)

Industry	*1933*	*1935*	*1936*	*1937*
Ferrous metallurgy (natural fluorspar)	19.20	28.31	34.65	40.55
Aluminum (cryolite)	5.00	6.00	8.00	10.00
Insecticides, etc. (NaF, etc.)	3.60	11.13	15.82	23.11
Silicates (total)	1.40	2.60	4.00	5.50
Miscellaneous	0.25	0.55	0.75	1.00
Total	29.45	48.59	63.22	80.16

Source: Yakubovits, 1936, p. 7.

While it is clear from the table above that the crisis in the quan-

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tity of Soviet fluorspar production had passed by 1935, the quality of the product was still unsatisfactory. The hand-sorted product of the Transbaikal mines was heavily contaminated by silica (up to 15 per cent), rendering it unfit for chemical use. Furthermore, recoveries here were extremely low: 40 per cent at Kalangui, 55 per cent at Abagaitui, 55–60 per cent at Otsolui (Luchitskii, 1937, p. 312 ff.). Exceptionally high-grade fluorspar from Amderma was available, but operating costs at this remote Arctic outpost were so high — nearly four times those for the Transbaikal — that a cutback in production had to be planned (cf. Lurye, 1937, p. 66; Kisel'gof, 1937; Yanson, 1937, p. 17).

Consequently, a considerable program for building concentration plants was in progress by 1937. At Kalangui, the capacity of the underground workings had been raised to 80,000 m.t. by 1935, but the capacity of the concentration plant under construction was limited by meager water supplies to 25,000 m.t. of concentrates ranging from 92 per cent to 75 per cent CaF_2 (Luchitskii, 1937, p. 312). At Aurakhmat, the concentration plant was to attain a capacity of 31,000 m.t. of finished product by the end of 1937 (delayed a year from the original schedule). Technical difficulties from low-content, crumbly ore were being met; the cost of a low-grade end product was 200 rubles per ton, nearly twice that for the old-fashioned Transbaikal mines (Luchitskii, 1937, p. 313; Lurye, 1937, p. 66). Finally, Takob in the Tadzhik S.S.R. marked the site of a newly begun plant to yield 30,000 m.t. of concentrate per year (Luchitskii, 1937, p. 179).

Production figures for 1937 and later years have not been discovered. However, Kholmyanskii stated in 1946 that not a single section of the Takob plant had been finished by that time. Yet general reviews of the Soviet mineral position (Anon., 1939*a*, and Gol'denberg, 1940) indicate only a mild deficiency of fluorspar supply and a low priority for this problem on the eve of World War II. It is not unlikely, therefore, that fluorspar output may have reached 80,000 to 90,000 m.t. by 1940. But during the war fluorspar needs contracted, as has been stated previously. Furthermore, it is extremely doubtful whether Amderma maintained significant output at this time, in view of the disruption of the Northern Sea Route. From Bykhover and Rozin's review (1947, p. 270), no by-product fluorspar seems to have been produced at the Khaidarkan antimony-mercury-

X 433 fluorspar deposit, which began operation during the war (see the
X 135 section on mercury). In all, fluorspar output in, say, 1944, may not
316 have exceeded 50,000 to 60,000 m.t.

By 1950, Soviet Hypothetical Standard requirements for fluorspar had risen again to 82,000 m.t., and probable actual consumption, to some 120,000 m.t. Nevertheless, since abundant fluorspar supplies are now available from Eastern Germany and possibly Northern Korea, and since Soviet fluorspar production has been marked by extremely high costs and low efficiency, we do not believe that domestic output has expanded appreciably since the war.

Satellite Fluorspar Output. Germany has long been one of the world's great producers of fluorspar. In 1942, according to *Mineral Trade Notes* (vol. 21, no. 2, p. 32, 1945), the present Soviet Zone alone yielded 84,407 m.t. The same source (vol. 23, no. 2, p. 48, August 1946) gives North Korean output in 1944 as 68,800 m.t.; however, prewar production was much smaller, with a peak of 15,655 m.t. in 1937 (Meisner, 1939, p. 364).

TABLE 76

Soviet fluorspar ore reserves as of January 1, 1937 (thousands of metric tons)

Region	*Measured*		*Total*	
Eastern Siberia (Transbaikal)		645.9		1058
Kalangui	300.0		575	
Solonechnoye	309.3		399	
Abagaitui	36.6		84	
North Russia: Amderma		894.5		2102
Turkestan		667.3		1710
Aurakhmat	251.6		667	
Takob	415.7		1043	
Total, U.S.S.R.		2207.7		4869

Source: Gubkin, 1938*b*.

X 135 *Fluorspar Reserves and Deposits.* The Hypothetical Standard fluorspar needs of the U.S.S.R. to 1970 are some 4.8 million m.t. According to Gubkin (1938*b*), Soviet fluorspar ore reserves, averaging about 50 per cent CaF_2 content, totaled 13.6 million m.t. as of January 1, 1937; of these, 2.25 million m.t. were measured. The reserves of the deposits being currently operated or under development at that time are shown in Table 76. Taking into account the average tenor of Soviet fluorspar ores, the low recoveries previously 135x mentioned, and depletion to date (about 1.5 million m.t.), the margin of reserves may not appear great. But this position would be transformed by the introduction of modern flotation methods, as contemplated by Luchitskii (1937, p. 226) and his associates. Their experiments achieved the results given in Table 77. Also, cognizance must be taken of presently marginal and undeveloped reserves, e.g., Khaidarkan in Turkestan and Zaliv Kresta on the Bering Sea (Far East). With these points considered, the Soviet fluorspar-reserve position appears strong.

From a geological standpoint, the fluorspar deposits of the U.S.S.R. may be divided into two groups. (Betekhtin, 1946, pp. 312–315; Dvorshchan, 1935; Merenkov and Muratov, 1942, pp. 117–129; Gubkin, 1938*b*). The first, comprising those of the Transbaikal and Zaliv Kresta, is associated with granitic intrusions into sandstones and clayey shales of Jurassic age. The ores of this group are uncontaminated by sulfides, but often contain high silica. Thus, Kalangui ore runs from 62.6 to 98.5 per cent CaF_2; from 0.8 to 38.6 per cent SiO_2; from 0.04 to 5.57 per cent Fe; and from 0.02 to 1.84 per cent S. Assays at Solonechnoye showed 43.1 to 91.5 per cent CaF_2 and 5.4 to 50.9 per cent SiO_2, while the small deposit at Abagaitui evidenced high purity, with an average of 90–92 per cent CaF_2 and 2–4 per cent SiO_2. Analyses of the Zaliv Kresta ore, with 850,000 m.t. of indicated ore, are unavailable. (See Luchitskii, 1937, pp. 7–68; Fersman, 1940, pp. 561–576, 621.)

TABLE 77

Experimental fluorspar recovery from Soviet ores

Deposit	*CaF_2 Content (per cent)*		*Recovery (per cent)*
	Feed	*Concentrate*	
Kalangui	65.63	97.26	90.0
Solonechnoye	79.6	97.28	87.7
	72.0	92.76	90.0
Amderma	47.5	98.6	92.4
Aurakhmat	53.06	96.25	78.6
	69.7	96.12	94.7
Takob	44.3	—	90.2

Source: Luchitskii, 1937, p. 179.

x/135 Deposits of the second group — Amderma, Aurakhmat, Takob, and Khaidarkan — apparently derive their origin from granitic intrusions of Paleozoic age (Silurian and Upper Paleozoic). The ores, however, have been subjected to hydrothermal redeposition in tectonic cracks, and occur either in lenses or disseminated through breccia. Barite and sphalerite (ZnS) are common accessory minerals. Great variations in the purity of fluorspar found in these deposits are consequently present. Thus, at Amderma, lens ores average 80 to 97 per cent CaF_2, but the disseminated ores, which contain the overwhelming bulk of the reserves, run only from 40 to 54 per cent CaF_2. Aurakhmat ores range from 33.7 to 54 per cent CaF_2. Takob ores range from 47.7 to 51.4 per cent CaF_2, but the presence of commercial quantities of lead (1.59 per cent), zinc (1.00 per cent) and silver provides important compensation. The concentration plant under construction for a decade up to 1946, as previously mentioned, is to have a capacity of 30,000 m.t. of commercial fluorspar and 1,200 to 1,400 m.t. of lead annually. Finally, Khaidarkan has enormous quantities of submarginal ore averaging 19 per cent CaF_2; according to Suloyev and Ponomarev's initial study (1935, p. 73), these totaled 1,632,000 m.t. Gubkin (1938*b*) is even more optimistic, guessing the reserves at 7.5 million m.t. As is mentioned in the pertinent sections, Khaidarkan is primarily important as a source of mercury and antimony, with fluorspar as a possible by-product (Luchitskii, 1937, pp. 120–151).

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x 433 *Mica: Muscovite, Phlogopite, and Vermiculite. Summary.* Between 1926 and 1939, the output of muscovite and phlogopite mica cuttings in the U.S.S.R. increased some twenty times. This permitted a corresponding shift from moderate mica consumption, based primarily on imports, to self-sufficiency at 50 per cent above Hypothetical Standard supply levels, a condition called forth by the great expansion of the Soviet electrical industry in intervening years. Also, Soviet output of ground mica began during the mid–1930's. Since World War II, additional mica resources in Korea, Finland, and possibly Rumania have come under Soviet control. The muscovite and phlogopite mica reserves of the U.S.S.R. are unquestionably very large, although they have been but fragmentarily surveyed. A significant hindrance to the development of Soviet mica deposits is, however, their inaccessibility and remoteness from consuming centers; all the deposits are located in Eastern Siberia. Finally, the Soviet

Union has small ascertained but large possible resources of vermiculite mica; production of this mineral had not begun up to World War II. 135x 433x

Muscovite and Phlogopite Mica: Production, Foreign Trade, and Consumption. In 1926, the U.S.S.R. produced 410.4 m.t. of raw phlogopite mica from Slyudyanka at the southern tip of Lake Baikal, and 74.3 m.t. of raw muscovite mica, largely from numerous small deposits in Karelia and from Biryusa in Eastern Siberia. From the raw mica at Slyudyanka, 49.7 m.t. of sheets and other cuttings were recovered; of these, 3.16 per cent exceeded 90 cm^2 in area, an additional 5.30 per cent exceeded 65 cm^2, 21.5 per cent was over 40 cm^2, while 48 per cent was greater than 20 cm^2, and the remainder (22.0 per cent) over 10 cm^2. The recovery of mica cuttings from the raw muscovite mica produced in the U.S.S.R. in 1926 was extremely small, although exact figures are unavailable (Geological Committee, 1927, pp. 643–651). 135x 433x 439

The bulk of cut mica consumed in 1926 thus came from imports, which totaled 76 m.t. With these, Soviet cut-mica consumption in that year closely corresponded to Hypothetical Standard. The consumption of ground mica then was apparently negligible.

During the next decade, Soviet raw-mica output soared to 5,721 m.t. in 1933 and 8,274 in 1935; then to 10,796 m.t. in 1937 and 12,900 m.t. in 1939. The goal for 1942 was 24,000 m.t. (*Minerals Yearbook*, 1937, p. 1268; Betekhtin, 1946, p. 252; *Anon.*, 1939*a*, p. 15). Slyudyanka remained the largest producer; by 1934–1936, it was yielding 4,000–5,000 m.t. of raw mica annually (Luchitskii, 1939, p. 322). The recovery of cuttings achieved is not known, although the 1936 projected capacity of the plant at Irkutsk working this mica seems indicative: 450 m.t. of cuttings and 2,000 m.t. of ground mica (State Planning Commission, 1936, II:466–467). From Luchitskii's data (1939, p. 334), it appears that some diminution in the proportion of large sheets produced had taken place by 1935. In that year, 3.4 per cent exceeded 90 cm^2; an additional 6.2 per cent, 65 cm^2; 12.2 per cent, over 40 cm^2; 21.6 per cent, over 20 cm^2; 31.6 per cent, over 10 cm^2; with 25.0 per cent down to 4 cm^2.

In addition to Slyudyanka, the muscovite-mica deposits of Biryusa and the Mama-Vitim group had become important by the mid-1930's. The raw-mica output of Biryusa in 1937 was some 2,500–2,800 m.t., with an unknown recovery of sheets and splittings. The Mama-

X/35 X4/33 439 Vitim group produced 2,416 m.t. of raw mica, with a 10 per cent recovery of cuttings. These, however, ran to small sizes; only 3.73 per cent exceeded 65 cm^2; an additional 20.57 per cent were over 20 cm^2, while over 75 per cent ranged down to 6 cm^2 (Betekhtin, 1946, pp. 253–256).

To summarize: the Soviet output of mica cuttings in 1937 probably comprised some 10 per cent of its raw-mica production, or roughly 1,000 m.t. Of this, about half represented small sheets, under 20 cm^2. Since Soviet foreign trade in mica had become negligible by 1937, this production closely approximated consumption, which was now about 150 per cent of Hypothetical Standard. An appreciable consumption of ground mica by the Soviet rubber and asphalt-tile industries is also indicated by Luchitskii (1939, p. 344).

Statistics on Soviet mica output after 1939 are completely lacking, as are production goals. Nevertheless, it should be noted that Lend Lease shipments of mica reached an appreciable level — 68,913 lb — only in 1943 (Bureau of the Census, 1944, n.d., 1946*a*, 1946*b*).

X/35 X433 *Muscovite and Phlogopite Mica: Satellite Resources.* About twenty deposits of phlogopite mica are known in Korea, which had a modest output of the mineral prior to World War II, reaching 87 m.t. in 1935. In 1944, however, Northern Korea alone produced 400 m.t., but it is uncertain whether or not this datum represents raw mica (Luchitskii, 1939, p. 257; Friedensburg, 1938, p. 322; *Mineral Trade Notes*, vol. 23, no. 2, p. 48, August 1946).

In Soviet-dominated Eastern Europe, only Finland is definitely known to have phlogopite-mica deposits, which, however, have never been worked (Luchitskii, 1939, pp. 258–259). Rumania has also been credited with 628 m.t. of mica production in 1943, but neither confirmation of this report nor further details have come to light (*Minerals Yearbook*, 1946, p. 795).

X/35 *Muscovite and Phlogopite Mica: Reserves and Deposits.* Deposits of these minerals are found solely in Eastern Siberia. The officially summarized mica reserves of the U.S.S.R. are modest: 95,400 m.t. for total muscovite, including 7,970 m.t. measured; and 13,000 m.t. for total phlogopite, including 6,700 m.t. measured, as of January 1, 1938 (State Planning Commission, 1939, p. 175). But they actually represent only a small portion of the mica resources of the Soviet Union. It is certain, particularly from Fersman's monumental study on pegmatites, that the Mama-Vitim area (including the Severnyi,

Lugovka-Slyudyanka, and Sogdiondon deposits) — credited with 135A
but 3,960 m.t. of measured and 25,445 m.t. of indicated reserves as of January 1, 1939 — actually possesses tremendous resources, running into millions of tons of raw mica (Fersman, 1940, esp. pp. 582–601; Betekhtin, 1946, pp. 253–256). The other muscovite-mica deposits in the Soviet Union are much smaller: Biryusa, with 2,165 m.t. measured, plus 30,247 m.t. indicated, as of January 1, 1937, and Kondakovskoye, with low-quality mica, only 756.2 m.t. measured and 2,432 m.t. indicated, but with 250,000 m.t. inferred, also as of January 1, 1937 (Gubkin, 1939).

Soviet phlogopite resources are more restricted. Slyudyanka is now virtually exhausted. On the other hand, large-scale discoveries have definitely been made in the Aldan region of Yakutiya. Their commercial development began in 1942 (Bykhover and Rozin, 1947, p. 272). Pavlovskii's (1944) report on this group shows that 19 deposits have been found, with three — Emeldzhik, Kuranakh, and Chuga or Ust' Nelyuka — manifesting immediate economic promise.

The geological history of all these deposits has been broadly similar: pegmatitic intrusion into Pre-Cambrian crystalline formations. Details are available in Fersman (1940), Althausen (1935), Luchitskii *et al.* (1939), Merenkov and Muratov (1942, pp. 23–38), Pavlovskii (1944), and Suslov (1947, p. 255).

Vermiculite Mica. In 1933, the Soviet Union began a program of 316
research on vermiculite technology, as a basis for effective develop- 433'
ment of its deposit at Buldymskoye in the Urals. Although the per-
tinent problems had seemingly been solved by 1939, actual com- 135A
mercial output of vermiculite insulating materials had not yet started then (Zubarev, 1939).

The deposition of vermiculite at Buldymskoye has been attributed to pegmatitic intrusions in ultrabasic serpentines, Upper Paleozoic in age. Thus, although the Buldymskoye deposit itself is small, with measured reserves of 29,000 m.t. and total reserves of 73,500 m.t. (January 1, 1937), the probabilities of other discoveries in the Urals are very great, since the requisite formations are widely distributed in this area. (Cf. Zubarev, 1939, pp. 18–23; Merenkov and Muratov, 1942, pp. 36–37.)

Piezoelectric Quartz Crystals. In 1940, Soviet production of this mineral was "modest," according to Fersman (1940, p. 623). The total value of the annual output of all semiprecious quartz at that

x 433 time was 250,000 gold rubles, but of this yield a large part was un-
x 135 questionably unsuitable for electronic and optical purposes, since the
316 crystals recovered from the main producing area, in the central
Urals, are characterized by frequent twinning and cloudiness. Dur-
[439] ing World War II, no imports of piezoelectric quartz crystals as such took place, although considerable numbers of crystal oscillators were incorporated in the vast amount of electronic equipment sent to the U.S.S.R. Neither production nor reserves of piezoelectric quartz have been found for the Soviet-dominated areas of Europe and the Far East.

While quantitative data on reserves are lacking, one gains the impression of substantial resources through examination of the geological literature: Fersman (1922–25, I:218–223, II, *passim;* 1940, p. 623); Merenkov and Muratov (1942, pp. 76–78); Betekhtin (1946, pp. 263–270). All of the deposits are associated with granitic pegmatites. The two largest deposits are extremely inacessible, in the roadless wilds of the northern Urals (Neroika) and the Pamirs (Barnavandzh) of Turkestan. The Neroika deposit consists of pegmatite veins of Alpine age dissecting earlier metamorphosed shales. The composition of these veins is complex; in addition to quartz, chlorite, rutile, apatite, brucite, and sphene are common. Colorless quartz crystals up to 70–80 cm in length and 80–100 kg in weight have been found. Unfortunately, cracks and cleavages in these crystals are frequent. At Barnavandzh, the quartz veins dissect Paleozoic quartzites and marbles. The crystals found are small but of excellent quality, according to Merenkov and Muratov (1942, pp. 76–78).

The deposits of the central Urals — Kamenka-Sinarka, Nevyansk, and Murzinka — are of Alpine age. Crystals are found either in gold-bearing lodes intruding into greenstone shales, porphyry, and tuff, or in placers. As stated earlier, these crystals are but rarely of piezoelectric quality. In contrast, the Volodarsk-Volynskii deposit in the Ukraine does carry an appreciable proportion of piezoelectric-grade quartz crystals. It is associated with the contact zone between Pre-Cambrian granites and even older basic gabbro-labradorite formations.

Strontium. General. Prerevolutionary Russia imported substantial quantities of strontium minerals, 598 m.t. in 1913, especially for refining beet sugar. During the first World War, domestic production from the Lyakan deposit in Central Asia developed, reaching 130

m.t. annually (Geological Committee, 1927, pp. 675–677). Under the 433^{x}
Soviet regime, however, neither production nor consumption of 135^{x}
strontium was manifest on an appreciable scale. The sole recorded 316
import comprised 11,000 lb of strontium nitrate from the United States in 1942 (Bureau of the Census, n.d.).

In 1946, however, the need for a revival of strontium production was realized by the Soviet government (Khandross, 1946). The country's known celestite reserves are adequate to maintain a moderate level of strontium production, although one far below Hypothetical Standard demand. No indication of strontium resources has been found for the Soviet satellites either in Europe or in the Far East.

Strontium Reserves and Deposits. Soviet celestite ($SrSO_4$) reserves 135^{x}
aggregate 24,000 m.t. and probably more, as opposed to Hypothetical Standard needs totaling some 150,000 m.t. through 1970 (Khandross, 1946).

The most important area of celestite deposition in the Soviet Union lies in North Russia, in the basins of the Pinega and Kuloi Rivers, especially near Priluk. The ore occurs in the form of concretions in Permian marls, and is characterized by high purity, with up to 98.16 per cent $SrSO_4$, and an average of 0.81 per cent $BaSO_4$ and 0.72 per cent $CaSO_4$. The reserves of the entire deposit group have not been assessed, but one ore body alone (at Sikhtovo) has been estimated to comprise 8,000 m.t. of reserves. In recent years, a few tons per year were produced here (Popova, 1935).

Near Lyakan in the Fergana Valley of Turkestan is another celestite deposit. The ore fills numerous karsts in Cretaceous limestones. In 1927, measured reserves aggregated 100 m.t.; total reserves were about 16,000 m.t. (Geological Committee, 1927, pp. 675–677). As mentioned previously, strontium output at this deposit reached 130 m.t. annually during World War I.

Chapter IX

THE DEVELOPMENT AND POTENTIALS OF RUSSIA'S MINING INDUSTRIES

3/6 433 Despite serious setbacks caused by losses during World War II, Russia's mining industries have undergone tremendous expansion over the past quarter century. This has been particularly true for the production of nonferrous metals and fertilizer basics. Furthermore, the last decade has witnessed a pronounced eastward shift in production, and considerable maturation in mining and refining technology.

Nevertheless, the Soviets have been unable to meet their own ambitious goals, intended to permit a breakneck pace of industrialization and economic expansion. The chronic shortage of minerals resulting from this failure has had numerous consequences. [439] The U.S.S.R. has shifted from a net mineral-exporting to a mineral-importing balance of foreign trade. It has sacrificed the healthy growth of housing, agriculture, the transportation network, and light industry to the overriding needs of heavy manufacturing. It has accepted serious waste from the widespread use of substitutes that have been frequently substandard and short-lived.

In its search for military security, the Soviet Union has also striven to achieve self-sufficiency, through the development of domestic production and through assiduous stockpiling. These efforts have been but partially successful. During World War II, the enormous supplies sent by the United States, Canada, and the United Kingdom were indispensable for Soviet survival. Today, although peacetime internal needs for most minerals can probably be met from domestic output, the requirements of the satellites and, above all, the potential demands of a full-scale, prolonged war raise critical problems, especially in regard to nonferrous metals, petroleum, and sulfur minerals.

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The known mineral reserves of the Soviet Union are extremely 135 large. In most ferrous metals and nonmetallics, and in fuel, they are 316 adequate or abundant to permit self-sufficiency for twenty years or more of intensive economic development. On the other hand, the reserves of most nonferrous metals and other minerals such as diamonds and tungsten range from doubtful adequacy to negligible size. But the situation as presently known reflects primarily the pioneering stage of Soviet prospecting and mining development. Even the preliminary geological reconnaissance that sums up present knowledge of most of the Soviet Union has brought out, beyond question, the great structural diversity and virtually limitless ultimate potentialities of Russia's lands. The wealth of the Urals may well be duplicated in Turkestan and central Siberia.

The general outlines of Russia's mineral position are clear. In contrast, the more specific discussions that follow must be viewed as approximations subject to serious error. As this volume stresses throughout, and as Chapter II, "Sources and Definitions," has considered at length, the source materials underlying study of the Soviet mineral position vary enormously in reliability, from good to guesses. Their interpretation has also bristled with difficulties. Finally, unprovable assumptions have had to be made all too often.

1. *Production: Volume, Distribution, and Technology*

Between 1926 and 1937, total Soviet mineral output, as measured 316 in U. S. 1937 prices, increased almost fivefold (see Table 78). In 433 the latter year, Russia's mineral production approximated 23.5 per cent of the American, for a coverage including gold but excluding stone, sand, and gravel.

This growth in production was accompanied by important changes in composition. True, the production trends in pig iron and copper, coal and petroleum, and asbestos, barite, cement, fire clay, and gypsum corresponded roughly to the average. Yet relatively small increases were achieved in manganese ore, mercury, and platinum, as well as in china clay, salt, emery, and graphite output. In contrast, chromite, lignite, natural gas, magnesite, and talc production expanded at rates well above the average, while numerous minerals underwent tenfold growth and more. These included lead, zinc, and tungsten plus the nonmetallics bromine, corundum, fluorspar, mica, phosphate rock, potassium salts, pyrite, and natural sodium sulfate.

TABLE 78

Production of selected minerals in the U.S.S.R., 1926–1950

Mineral	*Unit*	*1926*	*1928*	*1932*	*1937*	*1944*	*1950*
Ferrous Metals							
Pig iron[a]	10^6 m.t.	2.22	3.22	5.98	14.0	(8.0)	18.9
Chromite	10^3 m.t.	30.1	25.5	62.1	(225)	x	x
Manganese ore	10^6 m.t.	1.33	0.77	0.83	2.75	(1.2)	(3.0)
Nickel, primary	10^3 m.t.	0	0	0	2.0	10.9	(21)
Tungsten (60% WO	m.t.	54	(40)	117	(2000)	(4500)	(2000)
Nonferrous Metals (primary)							
Aluminum	10^3 m.t.	0	0	0.9	37.7	82.7	(180)
Copper (electrolytic)	10^3 m.t.	17.4	22.0	38.1	90.8	(150)	(292)
Lead	10^3 m.t.	1.3	2.3	18.7	62.5	(50)	(144)
Mercury	m.t.	127	102[b]	200[b]	301[b]	(100)	x
Tin	10^3 m.t.	0	0	0	(0.5)	(4.5)	(9.0)
Zinc	10^3 m.t.	1.9	2.2	13.7	65.0	(45)	(128)
Gold	10^6 oz.	0.89	0.90	1.99	5.36	x	x
Fuels							
Coal	10^6 m.t.	23.5	32.4	57.5	109.7	(95)	(200)
Lignite	10^6 m.t.	2.3	3.0	6.9	17.6	(40)	(63)
Natural gas	10^6 m³	228	270	905	1980	(1000)	2600
Petroleum	10^6 m.t.	8.34	11.4	21.6	28.5	(19.0)	35.0
Other Nonmetallics							
Asbestos	10^3 m.t.	24.4	26.4[c]	60.2[c]	86.1	(35)	(157)
Barite	10^3 m.t.	14.4	x	x	70.0	x	x
Cement	10^6 m.t.	1.33	1.90	3.47	5.45	(1.7)	10.6
China clay	10^3 m.t.	182	x	x	293	x	x
Dolomite	10^3 m.t.	179	x	x	(1000)	x	x
Fire clay	10^3 m.t.	749	x	x	(2500)	x	x
Gypsum (calcined)	10^3 m.t.	292	241	475	1212	(330)	(2000)
Magnesite	10^3 m.t.	103	x	x	846	x	x
Phosphate rock[d]	10^3 m.t.	79.2	104.4	841	1948	(400)	(2500)
Superphosphates (18.5% P_2O_5)	10^3 m.t.	61.2	113	468	1454	(300)	2600
Potassium salts (22% KCl)	10^3 m.t.	0	0	78.5	2318	x	(2000)[e]
Pyrite[f]	10^3 m.t.	105	192	371	1113	(800)	(1700)
H_2SO_4 (100%)	10^3 m.t.	169	210	(600)	(1500)	(1100)	(2200)
Salt	10^6 m.t.	1.64	2.3	2.6	3.2	(2.0)	(3.9)
Soda ash	10^3 m.t.	136	215	(300)	532[g]	x	(650)
Sulfur, natural	10^3 m.t.	0	0	(19)	(80)	(85)	(100)
Talc and steatite	10^3 m.t.	3.0	x	x	25.6	x	x

TABLE 78 (Continued)

Mineral	*Unit*	*1926*	*1928*	*1932*	*1937*	*1944*	*1950*
Value of Mineral Production[h]							
Total	10^6 1937 U.S. dollars	239	309	582	1148	x	x
Excl. Gold	10^6 1937 U.S. dollars	208	278	512	960	711	1567

[a] Excluding ferroalloys (about 4 per cent of total).

[b] Meisner, 1939, p. 231.

[c] Meisner, 1939, p. 326.

[d] Including apatite concentrate.

[e] However, better recoveries permitted an increase in potassium-fertilizer output from 402,000 m.t. in 1937 to 850,000 m.t. in 1950.

[f] Including coal brasses, but excluding smelter-gas recoveries.

[g] For 1938.

[h] Gross values of missing figures, other than gold, interpolated proportionately for 1928 and 1932; for 1944 and 1950, value changes in the missing figures were assumed to be proportional to those of related known and estimated minerals. Totals exclude potassium salts, sulfuric acid, superphosphates, and soda ash.

Figures in parentheses are estimated.

x Output figures lacking.

Sources: Chaps. III–VIII, except as noted.

Finally, the production of still other minerals began during these years, albeit on small scales. Among the new developments were several metals: aluminum, antimony, beryllium, bismuth, cadmium, magnesium, molybdenum, tin, and vanadium-bearing naturally alloyed pig iron. New nonmetallics included natural sulfur, borax, iodine, and andalusite.

As World War II approached, the growth of Soviet mining was restricted essentially to nonferrous and ferroalloying metals. In addition, the experimental production of cobalt, rare earths, zirconium, and piezoelectric quartz crystals began. But the catastrophes of the war profoundly disrupted the Soviet mining industries. Even in 1944, after three years of effort and Lend Lease aid, the nation's total mineral output was barely three-quarters of the level reached in 1937. Much of this retrogression was a direct consequence of German advances. The Germans overran a great part of Russia's capacities for producing or refining pig iron, manganese, mercury, zinc, and zirconium, among the metals; the fuels, coal, lignite, and petroleum; and the nonmetallic minerals, cement, china clay, fire clay, dolomite, graphite, gypsum, phosphate rock (especially superphosphates manufacturing), and salt. The outputs of copper and lead,

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of petroleum and natural gas, and of barite and asbestos, apparently suffered from overworked equipment, inadequate maintenance, and the insufficiently rapid development of reserves. Yet significant advances also took place during World War II. Despite war losses, aluminum, nickel, and lignite production reached new heights. So too did the ferroalloys, tungsten, molybdenum, and vanadium; the nonferrous metals, magnesium and antimony; the refractory, andalusite; and bromine, essential for producing aviation gasoline.

By 1950, the Soviet mining industries had achieved a remarkable recovery, reaching a level more than 60 per cent above that of 1937, more than double that of 1944. As in the prewar period, important structural changes had taken place in minerals production since 1937. The most notable was the great increase in nonferrous and ferroalloying metals outputs proportional to the total. This embraced not only major metals such as aluminum, copper, nickel, and tin, but also lesser ones such as antimony, cadmium, cobalt, magnesium, molybdenum, and vanadium. Lead and zinc production in 1950 was about double that of 1937. Another significant change has been the increasing importance of coal and lignite relative to petroleum and natural gas, a trend the reverse of American experience.

Soviet achievements in mining, though impressive, have nevertheless failed to equal the country's plans. The output reached in 1932, at the end of the First Five-Year Plan, was but three-quarters of the optimal goal (if both are weighted at U. S. 1937 dollars). Only the production of fuels surpassed or approached the goals set; the contrasting failures in nonferrous metals and fertilizer basics were especially severe (compare Tables 78 and 79). The Second Five-Year Plan again fell a quarter short of the goals set. In general, ferrous metals and coal production approached their goals; for some nonmetallics, such as barite and potassium salts, the targets were exceeded substantially. On the other hand, the margins between expectation and achievements were especially great for nonferrous metals, petroleum, and various nonmetallics, e.g., asbestos and salt. In 1950, the Soviets, by and large, reached the goals of the Fourth Five-Year Plan; the one outstanding failure was in natural-gas production. At the same time, it should be noted that this Plan was not merely a repetition but in some instances an actual reduction of the goals set originally for 1942. By the earlier standard, the outputs of petroleum, fertilizers, salt, and sulfur basics were not yet satisfactory. We shall

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TABLE 79

Soviet mineral-production goals, 1932–1950

Mineral	*Unit*	*Five-Year Plan* First, 1932[a]	*Five-Year Plan* Second, 1937	*Five-Year Plan* Third, 1942	*Five-Year Plan* Fourth, 1950
Ferrous Metals					
Pig iron and ferroalloys	10^6 m.t.	10.0	18.0	22.0	19.5
Chromite	10^3 m.t.	x	225[b]	x	x
Manganese ore	10^6 m.t.	0.96	2.70	4.50	x
Nickel, primary	10^3 m.t.	—	6	x	21
Nonferrous Metals (primary)					
Aluminum	10^3 m.t.	—	80	132[c]	(180)
Copper (electrolytic)	10^3 m.t.	84.7	132	254	(248)
Lead	10^3 m.t.	x	120	x	(156)
Mercury	m.t.	x	x	(390)	x
Zinc	10^3 m.t.	77.4	100	x	130
Fuels					
Coal and lignite[d]	10^6 m.t.	75.0	152.5	230	250
Petroleum	10^6 m.t.	20.8	44.3	49.5	35.4
Natural gas	10^6 m^3	900	2500	5500	8400
Other Nonmetallics					
Asbestos	10^3 m.t.	150	200	230	x
Barite	10^3 m.t.	x	66.5	x	x
Cement	10^3 m.t.	6970	7500	10,000	10,500
China clay	10^3 m.t.	x	306	x	x
Gypsum (calcined)	10^3 m.t.	x	1200	2100	(2700)
Superphosphates (18.5% P_2O_5)	10^3 m.t.	2585	2510[e]	3510[e]	2720[f]
Potassium salts (22% KCl)	10^3 m.t.	x	1500	3400	x
Sulfuric acid (100% H_2SO_4)	10^3 m.t.	1450	2080	>3000	x
Salt (NaCl)	10^3 m.t.	3250	5000	x	(4600)
Soda ash	10^3 m.t.	x	750	1125	813

[a] Optimal plan.

[b] Yearly plan.

[c] Raised to 200,000 m.t. in 1938; cf. Gol'denberg, 1940, p. 8.

[d] Lignite unadjusted for lower heat value.

[e] According to Jasny (1949, p. 495), some 2.3 and 3.3 million m.t., respectively, in 18.5 per cent P_2O_5 equivalent.

[f] Concentration not known.

Sources: State Planning Commission, 1929, 1934, 1937, 1939; *Zakon o Pyatiletnom Plane*, 1946.

return to the relation between goals and actualities in Soviet mineral production in the discussion of self-sufficiency.

While the rise in total Soviet mineral output was more marked between 1926 and 1937 than between 1937 and 1950, the regional

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shifts in production were more extensive in the latter period (see Table 80). In 1926, 90 per cent of the country's mineral production, excluding gold, came from the Ukraine, the North Caucasus and Transcaucasus, and the Urals. The first area produced three-quarters of all Soviet pig iron and coals, half its manganese, the bulk of its refractories and salt, and all its mercury. Practically all Soviet petroleum and natural gas flowed from Caucasian wells; other important products from those regions were manganese, cement, coal, base metals, and barite. The Urals were Russia's sole or primary sources of asbestos, chrome, copper, magnesite, pyrite, and talc. Also significant was their production of pig iron, gold, tungsten, miscellaneous refractories, and salt, but they were notably weak in mineral fuels and cement. Russia's major gold producer in 1926 was Eastern Siberia.

In 1937, the shares of the Ukraine, the Transcaucasus, and the Urals in Soviet mineral production were unchanged from 1926, but that of the North Caucasus had fallen from 13.6 per cent to only 6.9 per cent of the national total. The strengthening of the Urals fuel position with new petroleum and expanded coal and lignite output, and the advent of nickel production in the Urals and of aluminum in the Ukraine and Northwest Russia, were, however, noteworthy. Also important was the emergence of lesser mineral-producing areas: Western Siberia, with coal, pig iron, manganese, zinc, and cement; Turkestan, with petroleum and coal, gold, lead, zinc, copper, chrome, tungsten, natural sulfur, cement, and salt; and Central Russia, with pig iron, cement, lignite for fuel and as a source of sulfur, fire clay, phosphate rock, and gypsum. Eastern Siberia monopolized Soviet tin output, and was the major supplier of tungsten, but its previous supremacy in gold had been wrested away by the Far East, thanks to the discovery and ruthless exploitation of the great Kolyma placers in the latter region.

Information on the distribution of mineral output in 1950 is far less complete and reliable than for the prewar years. Nevertheless, a basic eastward shift in mineral production since 1937 appears to be an unquestionable fact. Today, almost half of Russia's output of minerals comes from the Volga, the Urals, Turkestan, and Siberia, compared with little more than a quarter in 1937 and 17 per cent in 1926. Or, put in another way, the value of mineral production in the so-called eastern regions of the Soviet Union rose, at 1937 U. S.

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TABLE 80

Mineral production by 1946 economic regions, for 1926, 1937, and 1950 (millions of U. S. 1937 dollars)

Year	*Group**	*Economic Region†* *North-western*	*North-ern*	*Baltic*	*Central*	*Urals*	*Ukrain-ian*	*Volga*	*N. Cau-casus*	*Trans-caucasus*	*Turke-stan*	*W. Siberia*	*E. Siberia*	*Far East*	*Total*
1926	Ferrous metals..........	—	—	—	0.9	11.1	38.6	—	—	5.1	—	—	0.6	—	56.3
	Nonferrous metals......	—	—	—	—	4.2	0.3	—	0.3	0.5	0.1	—	—	—	5.4
	Fuels.................	—	—	—	0.8	2.3	36.6	—	24.3	47.9	3.2	3.6	1.3	1.3	121.3
	Nonmetallics...........	1.2	—	—	3.2	3.7	7.9	3.6	3.7	0.5	0.5	0.4	0	0.1	24.8
	Total................	1.2	—	—	4.9	21.3	83.4	3.6	28.3	54.0	3.8	4.0	1.9	1.4	207.8
	Gold..................	—	—	—	—	3.1	—	—	—	—	1.5	0.3	22.2	4.0	31.1
1937	Ferrous metals..........	—	—	—	14.3	58.2	205.6	—	—	(7.0)	(1.5)	29.6	(3.9)	—	320.1
	Nonferrous metals......	5.0	—	—	—	21.9	12.4	—	2.5	1.5	12.3	1.2	(0.6)	2.1	59.5
	Fuels.................	1.4	1.6	—	5.1	20.2	140.9	—	54.6	185.0	20.9	36.4	8.0	10.2	484.3
	Nonmetallics...........	7.2	—	—	14.1	18.6	29.7	7.8	9.1	2.9	3.0	2.3	0.3	1.4	96.4
	Total................	13.6	1.6	—	33.5	118.9	388.6	7.8	66.2	196.4	37.7	69.5	12.8	13.7	960.3
	Gold..................	—	—	—	—	(10.0)	—	—	—	—	(7.0)	(0.6)	(80.0)	(90.0)	187.6
1950‡	Ferrous metals..........	9.0	—	—	23.2	144.1	207.4	—	0.6	7.2	5.9	35.7	4.0	0.9	438.0
	Nonferrous metals......	7.9	—	—	—	86.5	10.4	—	4.6	8.9	63.4	6.5	5.9	7.9	202.0
	Fuels.................	4.7	24.3	—	20.6	86.9	180.0	36.1	53.0	142.4	86.0	88.4	16.6	25.4	764.6
	Nonmetallics...........	8.5	—	7.0	20.0	36.2	44.4	16.3	11.0	6.0	6.7	3.7	0.5	2.5	162.8
	Total................	30.1	24.3	7.0	63.8	353.7	442.2	52.4	69.2	164.5	162.0	134.3	27.0	36.7	1567.4

* Coverage as given in Table 78.

† For boundaries and definitions see Chap. II and Fig. 7.

‡ Data for 1950 are approximate, possibly ±10 per cent for the regional totals.

Sources: Chapters III–VIII. Also, for 1926, Geological Committee, 1927; TsUNKhU, 1932; for 1937, State Planning Commission, 1939, and Balzak, Vasyutin, and Feigin, 1949; for 1950, Anon., 1950; Bulganin, 1950; *Zakon o Pyatiletnom Plane*, 1946; Bardin and Bannyi, 1947; also adjustments from the Third Five-Year Plan, and detailed estimates based on resource and capacity data.

433 prices, from some $36 million in 1926 to $260 million in 1937, and
316 $766 million in 1950. These basic changes have resulted from a tripling in coal and lignite, a fourfold increase in petroleum and natural gas, a doubling in pig iron, the rise of aluminum production, and two-and-a-half-fold growths in copper and cement production in Russia's eastern regions. As a consequence of these changes, the eastern regions not only have become even more predominant in nonferrous metals production than before World War II, but they have also eliminated their prior weaknesses in fuels and ferrous metals.

At the same time, the total output of the western regions has recovered from the war and then risen moderately, reflecting growths in coal and lignite, cement, and pig-iron production, and a new nickel industry in Northwestern Russia, which have more than offset the decline of petroleum output in the Transcaucasus. Thus, the Ukraine in 1950 was once again Russia's primary mineral-producing area, surpassing the output of the Urals by nearly 30 per cent. In the second rank were the Transcaucasus and two new areas—Turkestan, predominant in copper, lead, zinc, chromite, and sulfur, and important in fuels, phosphate rock, and salt; and Western Siberia, surpassed only by the Ukraine in coal, and only by the Ukraine and the Urals in pig iron.

A final aspect of the rapid increases in Soviet mineral production over the past twenty-five years has been considerable progress in mining and refining technology. In 1926, the technological problems of the Soviet Union were essentially simple, readily soluble by pre-World War I methods. In general, the use of good-grade, high-content ores, a fair margin of capacity, and a limited range of production characterized mining. A good deal of the product, especially in petroleum and manganese, was exported in crude form, while ferroalloys and refined nonferrous metals were largely imported. Platinum-metals refining and fabricating, and pioneer geochemical and gravimetric investigations appeared to have been the sole areas of advanced technique at that time (Geological Committee, 1927, pp. 523–558; Betekhtin, 1935). The geochemical researches, undertaken particularly by Fersman, led to important discoveries of rare metals in the Kola Peninsula and the Transbaikal; the gravimetric studies determined subterranean ridges and domes along the eastern margins of the Eastern European platform, thus laying the foundations for later successful prospecting for petroleum and salines (Fersman, 1940; Molodenskii and Fedynskii, 1947; Arkhangel'skii, 1941, pp. 50–104, based partly on magnetometric data). 316 433

During the 1930's, the technological problems of the Soviet mining industries changed radically. Vastly expanded production forced the use of less desirable ore fractions, particularly high-sulfur Donets coking coals, and Krivoi Rog and Urals iron-ore fines. The new deposits under development were often characterized by low-grade and heavily contaminated ores, notably so for Kazakhstan porphyry copper, Urals coals and lignites, Western Siberian zinc-laden iron ores, and Tikhvin and Kamensk bauxites. Insatiable economic and military demands forced the tremendous overloading of capacities, e.g., blast furnaces and copper smelters. The production of new minerals, such as antimony and tin, and the beginning of domestic ferroalloy output presented unforeseen difficulties. So too did mastery of more advanced imported equipment for flotation, petroleum cracking, contact manufacture of sulfuric acid, and so on. The net result was extraordinary waste. Thus, in 1937, Soviet concentration and refining recoveries averaged 20 per cent below foreign practice, with exceptionally poor performances in antimony, fluorspar, gold, graphite, petroleum, and potash processing (see Table 3). Product standards were often poor: high-ash, high-sulfur coke, and waterlogged china clay are illustrations. Finally, the inability to break technological bottlenecks at times inhibited production, e.g., of asbestos, graphite, and copper-by-product pyrite. 325 316 433

During and since World War II, many of these difficulties were overcome, in substantial part because of the great material and technical assistance provided by the United States and the British Commonwealth. True, overuse of equipment and inadequate maintenance led to partial breakdowns in base-metals and petroleum production. Yet greater experience and improvements in flow sheets, such as the wider use of coal-washing and iron-ore agglomeration units, have raised recoveries (which averaged 10 to 15 per cent below U. S. practice in 1947), and standards, notably for antimony, asbestos, and graphite (see Table 3). The recoveries of by-products, especially cobalt and molybdenum, and the use of very low-grade ores, e.g., tin, are now moderately successful (see Bibikova, 1946; Titkov, 1946). A contributing factor in this regard has been the establishment of a central rare-metals refining plant at Chelyabinsk,

316 modeled on an American prototype. The degree to which the Soviets
433 are using advanced American and German methods, notably heavy-
325 media separation, is uncertain, although the fact of their experimental use in 1946–47 appears clear (see Mitrofanov, 1946, 1947; Bochvar, 1946). Above all, important results have been gained in rehabilitating war-damaged mines. For example, the Soviets pumped out 14 million cubic meters of water and mud from the Krivoi Rog iron mines between 1944 and 1947, and reëstablished them as the country's leading iron-ore producers by 1950 (Notarev, 1948).

Nevertheless, the Soviet Union today still lags appreciably in mining and refining technology. Primitive techniques, as in sodium sulfate mining, and primitive equipment, such as venerable charcoal blast furnaces, are still evident. The problems of using low-grade andalusite and barite resources have not yet been solved. Nor have those of sulfur contamination in coking coal and petroleum and of zinc contamination in iron ore yet come under control. Low purities characterize much of Soviet metal production, for example, beryllium, cobalt, and nickel ingots (Marienbakh, 1947). Refractory life is still short (Budnikov and Zeitlin, 1946; Polakowski, 1951). The range of ferroalloys in standard production is both limited and conventional (Agapov *et al.*, 1947; Shimkin, 1950*b*). As mentioned earlier, geochemical and gravimetric prospecting methods are advanced, but electromagnetic methods and experimental seismology appear yet to be immature (cf. references in Gamburtsev, 1947; Tikhonov and Zaborovskii, 1947).

316 The historical development of mineral production in the Soviet
433 Union has exhibited a series of interesting parallels and contrasts to the American experience of the twentieth century. In the United States, mineral output increased from $1.25 billion in 1902, to $3.02 billion in 1917, $4.72 billion in 1937, and $6.06 billion in 1947 (all valued in 1937 prices, with the totals excluding gold, stone, sand and gravel). Thus the *relative* rate of growth in the Soviet Union between 1926 and 1937 was nearly twice that of the United States during its period of fastest growth, 1902–1917. For the entire time spans, 1926 through 1950 in the U.S.S.R. and 1902 through 1947 in the United States, the Soviet average rate of annual *relative* increase has been triple the American. It should be emphasized, however, that the average rate of *absolute* increase in the United States has been almost twice as great as in Russia for the entire

time spans considered. Both countries received serious setbacks in 316
production, from the Great Depression and World War II, respec- 483
tively. Their rates of absolute growth since then, i.e., 1937–1947 for the United States, 1944–1950 for the Soviet Union, have averaged, in both cases, some $140 million annually, the highest achievements to date for either country. As a percentage of American mineral production, in the same year Soviet output in 1950 was but slightly higher than in 1937 — under 25 per cent and 20.3 per cent, respectively. In 1926, it had been less than 5 per cent the American output for the same year.

The structural trends in Soviet mineral production over the past 328
quarter century have shown both convergences toward, and diver- 433
gences from, American patterns. Notable convergences may be found
in the proportion of nonferrous-metal and nonmetallic-mineral out- 316
puts to total production. Thus, nonferrous-metals production in the United States fell from 14.4 per cent in 1902 to 10.2 per cent in 1947; in the Soviet Union, nonferrous-metals output increased from 2.6 per cent to 12.8 per cent of the total, between 1926 and 1950. Again, the Soviet production of nonmetallic minerals other than fuels dropped between 1926 and 1950, from 12.2 per cent to 10.7 per cent of the aggregate; in the United States, it rose from 4.1 per cent in 1902 to 10.1 per cent in 1947. Ferrous metals and fuels have been the areas of structural divergence. In the Soviet Union, a slight rise in the relative importance of ferrous metals has taken place, from 26.9 per cent to 27.8 per cent; in the United States, on the contrary, ferrous metals have declined in significance, from 21.0 per cent to 14.0 per cent of the total. Conversely, fuels have risen, in the American experience of 1902–1947, from 60.5 per cent to 65.7 per cent of total output. Soviet data for 1926 through 1950 show, however, a drop from 58.3 per cent to 48.7 per cent.

In both the Soviet Union and the United States, the development 316
of mining has involved a process of measurable decentralization. 433
Interestingly enough, this process has been more pervasive in American than in Soviet experience, despite the concentrating influence of a highly developed transport network and nation-wide competition in the former country, and a policy of systematic regional autarchy in the latter. In Russia, it is true that the share of the Ukraine, the leading economic region in mineral output, fell from 40 per cent to 28 per cent of the national total between

316 433 1926 and 1950. Yet as late as 1950, only five out of thirteen economic regions — the Ukraine, the Urals, the Transcaucasus, Turkestan, and Western Siberia — produced 80 per cent of the country's aggregate, with the others contributing less than 5 per cent each. The United States was also characterized by extreme concentration of mineral output in 1902, when only two economic regions, the Mid-Atlantic and East North Central, produced 65 per cent of the total; five out of nine regions yielded less than 5 per cent each, if gold is excluded. By 1947, however, no region was contributing more than 29 per cent of the national total, while only two — the West North Central region and New England — produced less than 5 per cent each. (See Shimkin, 1952.)

2. *Foreign Trade*

439 Information on Soviet foreign trade in minerals is relatively good for 1926–1937 and 1941–1944, but data on the later prewar and the postwar periods are fragmentary and unreliable.

Before World War II, Russia's greatest foreign suppliers of minerals were the United Kingdom, the United States, and Germany for *nonferrous metals* and *ferroalloys*, and Germany, Czechoslovakia, and Poland for *iron and steel*, huge imports of which were essential to Soviet industrial construction in the early 1930's. In general, Soviet mineral imports were restricted to these few commodities. But they increased fivefold in volume (in constant prices) between 1926 and 1937, as can be seen from Table 81. At the same time, a growing proportion of these imports, about a third in 1937, was for strategic stockpiling rather than current consumption. Such stockpiling, embracing tin, nickel, tungsten, molybdenum, and lead, primarily, proved of great service to the Soviet Union from 1939 through 1941, years when its pact with the Nazis had cut off Western supplies, and when the economic strains of frantic armament and the Finnish war were most severe.

After the German attack, in 1941, the aid sent by the United States, Canada, and the United Kingdom was indispensable to Russia's survival. For example, even in 1944, when Soviet recovery from the early disasters of the war had become appreciable, Lend Lease provided *nearly a quarter* of Russia's visible mineral supplies. During the entire war period, *most* of the Soviet supply of aluminum, cadmium, copper, diamonds, mercury, molybdenum, ferro-

49: Shimkin E-4 (no date) 1953 R1 Soviet Union R1

vanadium, and zinc came from the West. Abrasives, bromine, cobalt, graphite and carbon products, iron and steel, lead, nickel, aviation gasoline, and tin (in the forms of tin plate and bronze) were also shipped in very sizable quantities. Deficiencies in Soviet processing capacity even forced imports of such normal surpluses as asbestos, ferrochrome, and ferromanganese. Furthermore, *Lend Lease was used, toward the end of the war, to rebuild stockpiles to prewar peaks or higher*. Stockpiled commodities appear to have included cadmium, copper, diamonds, molybdenum, nickel, tin, tungsten (largely from China), ferrovanadium, and zinc (see Table 97). Also, the large amounts of mineral-processing, particularly petroleum-cracking, equipment sent should not be forgotten.

Since the war, Soviet mineral imports appear to have resumed approximately the 1937 level. In contrast to prewar years, however, the largest part of these imports, in value, has consisted of petroleum from Rumania and Austria and coal from Poland. Other imports from Poland and Eastern Germany probably include uranium, zinc, cadmium, lead, and arsenic, as well as barite, bromine, fluorspar, and potash. Hungary is an important supplier of bauxite to the Soviet Union; Finland, of copper. Probable imports from Manchuria and North Korea include pig iron, tungsten, molybdenum, talc, lead, and zinc; from southern China, tungsten, tin, and antimony. Copper, diamonds, tin, and pyrite are known to have come from Western sources.

In prewar years, Soviet mineral exports exceeded imports by a substantial margin (see Table 82). Between 1926 and 1937, these exports increased by more than five times, and changed radically in composition, although ferrous metals, platinum, and asbestos remained important throughout. Petroleum and coal exports reached a peak in 1932, and were thereafter superseded by gold; fertilizer, especially apatite, exports became significant in the late 1930's. Russia's greatest customers were the United States (gold, platinum, and manganese ore), Italy (petroleum and coal), France (manganese ore and petroleum), and Germany (petroleum, manganese, asbestos, and platinum). Data on Soviet postwar exports are almost totally lacking; those sent to the United States during the brief period of friendly relations in 1946 corresponded closely to the late prewar pattern of commodities. In addition, the U.S.S.R. is known to be supplying iron ore to Eastern Europe. Nevertheless, it is

TABLE 81

Mineral imports related to total visible supplies and stockpiling

Mineral	*1926*			*1937*			*1944*			*1947*		
	Imports		*Stockpiling*	*Imports*		*Stockpiling*	*Imports*		*Stockpiling*	*Imports*		*Stockpiling*
	(10³ m.t.)	*(% of t.v.s.)*[a]	*(% of t.v.s.)*[a]	*(10³ m.t.)*	*(% of t.v.s.)*[a]	*(% of t.v.s.)*[a]	*(10³ m.t.)*	*(% of t.v.s.)*[a]	*(% of t.v.s.)*[a]	*(10³ m.t.)*	*(% of t.v.s.)*[a]	*(% of t.v.s.)*[a]
Ferrous metals												
Iron and steel	62	3[a]	—	6	—[a]	—	387	5[a]	—	—	—	—
Molybdenum[b]	0.006	100	—	1.8	(90)	(30)	1.8	(77)	(48)	*	*	—
Nickel	0.023	100	—	16.9	81[d]	48[d]	8.9	48[d]	43[d]	—	—	—
Tungsten[e]	(0.7)	90	10	2.2	(52)	(30)	6.1	(60)	(40)	2.3	(70)	(25)
Vanadium[f]	.050	100	—	0.13[g]	x	x	0.5	x	x	—	—	—
Nonferrous metals												
Aluminum	1.8	100	—	2.5	6	—	172	67	—	—	—	—
Bauxite	—	—	—	—	—	—	—	—	—	189	(25)	—?
Copper	12.7	39	—	65.8	42	3	195[h]	57	(20)	(41)	(18)	(22)
Lead	21.9	95	—	42.4	40	16	24.0	(30)	(6)	x	x	x
Tin	2.1	100	—	25.5	(97)	(56)	(9.0)[h]	(33)	(33)	x	x	x
Zinc	13.2	89	—	2.9	4	[i]	99[h]	(68)	(38)	(30)	(30)	(10)
Fuels												
Coal	—	—	—	—	—	—	—	—	—	(9000)	(6)	—
Petroleum	—	—	—	—	—	—	630[j]	(12)[k]	—	(3000)	10	—
Nonmetallics												
Diamonds[l]	—	—	—	(25)	100	(—)	(620)[m]	100	(28)	x	x	x
Other abrasives	1.6	x	—?	1.2	x	—?	11.3	x	x	?	?	?

49: Shimkin E-4 (no date) 1953 RI Soviet Union RI

TABLE 81 (Continued)

Mineral	*1926*			*1937*			*1944*			*1947*		
	Imports		*Stockpiling*	*Imports*		*Stockpiling*	*Imports*		*Stockpiling*	*Imports*		*Stockpiling*
	(10^3 m.t.)	*(% of t.v.s.)**	*(% of t.v.s.)**	*(10^3 m.t.)*	*(% of t.v.s.)**	*(% of t.v.s.)**	*(10^3 m.t.)*	*(% of t.v.s.)**	*(% of t.v.s.)**	*(10^3 m.t.)*	*(% of t.v.s.)**	*(% of t.v.s.)**
Value, total imports (10^6 1937 dollars)[n]		14.7			75.9			213			(78)	
Incl. nonferrous metals . . .		11.9			56.4			159			(24)	
Incl. ferrous metals . . .		2.2			19.4			25			(5)	
Incl. estimated total stockpiling		1.0			25–30			55–60			8–10	

* Total visible supply (t.v.s.) includes imports plus current output. Primary metals only. Approximations in parentheses.

— None or insignificant.

x, Substantial, but quantitative data are lacking.

[a] Related to pig iron.

[b] Content.

[c] Possibly substantial imports from Manchuria and North Korea.

[d] Excluding the nickel content of naturally alloyed pig iron.

[e] As 60 per cent WO_3 equivalent.

[f] Ferrovanadium.

[g] For 1936.

[h] Including estimated contents in bronze and tin plate; excluding possible shipments via Japan.

[i] At least 7,000 m.t. drawn from stockpiles.

[j] Largely aviation gasoline.

[k] Percentage of visible gasoline supply.

[l] Industrial only (thousands of carats).

[m] Average, between October 1, 1941 and March 31, 1946.

[n] Iron and steel priced as pig iron, aviation gasoline, as ordinary motor fuel ($40.68 per m.t.) for better comparability with production, exports and consumption.

Sources: Chaps. III–VIII and Appendix II.

TABLE 82

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Mineral exports related to production

Mineral	1926		1932		1937		1946
	(10^3 m.t.)	(% of Production)	(10^3 m.t.)	(% of Production)	(10^3 m.t.)	(% of Production)	(U.S. only) (10^3 m.t.)
Ferrous metals							
Chromite	0.8	3	41.6	67	—	—	100.9
Iron ore	150	4	342	3	351	1	—
Manganese ore	673	51	416	50	1,001	36	242
Precious metals							
Platinum*	131	142	93.8	(94)	95	(63)	106.8
Gold*	—?	—	—	—	3,162	59	835
Fuels							
Coal	166	0.7	1,790	3	1,394	1	—
Petroleum and products	1,685	20	6,106	28	1,929	7	—
Nonmetallics							
Asbestos	7.17	29	16.5	27	27.3	33	2.5
Phosphate rock	—	—	45.1	5	512	26	—
Potash (22% KCl)	—	—	(4.2)	5	(150)	(7)	—
Value, total export, (10^6 1937 dollars)	28.8	12	67.0	11	149.6	13	37.9
Incl. manganese ore	7.1	51	4.4	50	10.5	36	2.5
Incl. fuels	14.7	12	55.6	15	19.3	4	—
Incl. gold	—	—	—	—	110.7	59	29.2

* Thousands of troy ounces.

Sources: Chapters III–VIII; Table 78; Appendix II.

439 clear that Soviet mineral imports today exceed exports by a substantial margin.

In general, Soviet foreign trade in minerals has been dominated since 1941 by two forces: the availability of cost-free, or at most, nominal-cost, imports via Lend Lease and, later, from the satellites; and the development of severe trade restrictions with the West since the end of World War II. As a result, only the prewar record affords some clues to the basic pattern of Russia's trade in minerals. Between 1926 and 1937, imports remained fairly constant as a percentage of total consumption, a fact also true for the American economy between 1902 and 1947. More unusual, however, was Russia's inability to develop exports of industrial minerals and, hence, its need to turn to gold transfers. An opposite course of events had been anticipated in the First Five-Year Plan; even in the Third Five-Year Plan, the asbestos and manganese-ore targets for 1942 were predicated on growing exports (see State Planning Commission, 1929, I; 1939, pp. 203–205). High costs of mineral production, weak marketing facilities, conflict between the goals of autarchy and maximally profitable exchange — all these were factors adverse to the growth of Soviet mineral exports. Their effects were intensified by the precipitous fall of world commerce during the 1930's. At the same time, though Soviet gold was always a high-cost product even with forced labor, its value was sharply increased by American devaluation in 1933, which thus favored Soviet transfers of gold to the United States. 439

3. *Consumption, Self-sufficiency, and Minerals Control*

For the period 1926–1938, direct information on Soviet mineral consumption and utilization, as distinguished from apparent supply, is relatively abundant and seemingly reliable. Among the more important sources are Guttsait and Spivak (1937) and Shul'kin (1940) for ferrous metals; Polyakov (1939) and Tsar'kov (1940) for nonferrous metals; and Probst (1939) for fuels. After 1938, the data become fragmentary, limited essentially to qualitative descriptions of utilization patterns and shortages (see esp. Agapov *et al.*, 1947). This fact, together with the grave uncertainties surrounding Russia's postwar trade in minerals, subjects any treatment of Soviet mineral consumption after 1937 to large probable error. It is our belief, however, that the values of the aggregate Index of Mineral Consumption for 1926 through 1950 are not far from the facts. In contrast, the data on consumption for individual minerals in later years must be considered purely as indications of probable trends. 433 316

With these cautions in mind, let us examine the apparent development of mineral consumption in the Soviet Union since 1926 (see Table 83). Weighting nineteen major minerals (excluding scrap) at U. S. 1937 prices, and relating the sum to a corresponding average for 1935–1939 in the United States designated as 100, gives the Index of Mineral Consumption used in this volume (see Chap. II and Appendix I). In the Soviet Union, this Index grew fivefold between 1926 and 1937, then rose another 11 per cent by 1940, to reach a level of 29.4. During World War II, the Index dropped

433
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TABLE 83

Mineral consumption in the Soviet Union, 1926–1950

Year	Value (10^6 U.S. 1937 dollars)	Index Series		
		U.S. 1935–39 ave. = 100	U.S., same year = 100	U.S.S.R. 1937 = 100
1926	187	5.2	4.7	19.9
1928	264	7.4	6.5	28.2
1930	378	10.6	10.4	40.4
1932	449	12.6	19.0	47.9
1934	650	18.2	23.3	69.3
1937	938	26.3	23.6	100.0
1940	1,047	29.4	23.2	111.7
1944	820	23.0	13.8	87.4
1946	873	24.5	15.7	93.1
1947	1,017	28.5	16.5	108.4
1948	1,189	33.4	18.4	126.8
1949	1,356	38.0	23.1	144.5
1950	1,538	43.2	—	164.0

Sources: For methods, Chapter II; for base data, Appendix II. Note the difference in coverage from Tables 80–82.

sharply at first, but then recovered substantially, as a result of Soviet efforts and Lend Lease. In consequence, consumption in 1944 totaled almost 80 per cent of the prewar peak. Since the war, Soviet mineral consumption has again been rising rapidly, to gain a level 47 per cent above the prewar high in 1950.

Mineral Consumption and Economic Growth. A study of the relation between mineral consumption and the movement of larger aggregative series of economic activity, such as the national product or total industrial output, meets with considerable technical difficulties in the case of the U.S.S.R. Official Soviet series, expressed in the so-called prices of 1926–27, are useless for our purpose because of their well-known deficiencies and biases. Alternative series have been computed by Western statisticians, some of which are utilized by us in the following discussion: first, to give a very tentative and general indication of the relation in Soviet experience between mineral consumption and gross national *material* product; second, to explore in somewhat greater degree the relation between mineral consumption and gross industrial output. In both instances reference is made to the corresponding statistical record in the United States. And third, the strikingly close agreement between the

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growth of mineral consumption and of domestic transportation is shown. 433
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Using Colin Clark's estimates (1949, no. 2/3, p. 9; 1947, p. 216; 1951, ch. iv; 1939, pp. 40–41, 68), but eliminating the value of *final* services, we obtain dollar values of Soviet gross national *material* product, which, after adjustment to the U. S. 1937 price level, can be related to the values of mineral consumption computed by us (Table 84). The ratio between the values of the gross national material product and of minerals consumed by the economy (the "value ratio") was 63:1 in 1928 and 28:1 in 1937 — a clear reflection of the intervening industrialization and urbanization. Of interest also is the contrast with a more highly industrialized society, the United States, where this ratio fluctuated between 14:1 and 16:1 between 1919 and 1948, excluding the years of the Second World War. Furthermore, each dollar's increase in mineral consumption in the U.S.S.R., between 1928 and 1937, was associated with 13–14 dollars'

TABLE 84

Estimated values and indices of mineral consumption, gross industrial output, and domestic transportation, U.S.S.R., 1928–1950 [489]

	(Billion U.S. 1937 Dollars)			*Indexes (U.S.S.R. 1937 = 100)*		
	(a)	*(b)*				
Year	*Mineral Consumption*	*Gross Industrial Output*	*Value Ratio (b/a)*	*Mineral Consumption*	*Domestic Transport**	*Gross Industrial Output*
1926	0.187	—	—	19.9	22	—
1928	0.264	5.93	22.4	28.2	29	33
1930	0.378	—	—	40.4	42	—
1932	0.449	—	—	47.9	49	—
1934	0.650	—	—	69.3	59	—
1937	0.938	17.8	19.0	100.0	100	100
1940	1.047	19.6	18.7	111.7	116	110
1947	1.017	—	—	108.4	98	—
1948	1.189	—	—	126.8	125	—
1949	1.356	—	—	144.5	146	—
1950	1.538	28.5	18.5	164.0	166	160

The figures refer to Soviet territory of the respective years.

* The total freight ton-mileage of the railroads, river transport, and (after 1934) automotive transport.

Sources: Mineral consumption, Table 83 and Appendix II; gross industrial output: text and Grossman and Shimkin, 1952; transportation, TsUNKhU, 1937, pp.194-195, 216-217; State Planning Commission, 1936, I:249–251; Khachaturov, 1939, pp. 545, 639–641; Hunter, [illegible] Ms; *Pravda*, 26 January 1951.

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increase in gross national material product (the "incremental-value ratio"), this being rather close to the incremental-value ratio of 12 experienced by the United States between 1909 and 1932, but much lower than the American incremental-value ratio for 1932–1941, namely, 18.5.*

Mineral Consumption and Industrial Output, 1928–1937. Let us now turn to examining the relations between the growth of the Index of Mineral Consumption and estimated industrial output, weighted at 1937 U. S. prices. "Industry" here comprises both manufacturing and mining, while the "gross value" of output used refers to the aggregate value of production for all industrial establishments, *without* eliminating the double counting that such simple aggregation entails. (This definition is somewhat narrower than the one generally used in Soviet statistics, which also encompasses timber cutting, fishing, and certain repair operations.) The sources used to estimate industrial output include primarily Wagenführ (1933, p. 54); Hodgman (1950, *passim*), Clark (1951, p. 186); Jasny (1951, p. 17); German Institute (1939, p. 77; 1940, p. 44). Because of the paucity and lower reliability of Soviet statistics after 1937, these sources generally go only to that year.

Between 1928 and 1937, Soviet mineral consumption rose somewhat faster (by 3.55 times) than did the *gross value of industrial output*, which increased 3.00 times, both magnitudes measured in U. S. 1937 prices (see Table 84). Both series, and especially the latter, are certainly subject to a considerable error, but the relation is likely to be real.

If the values of Soviet industrial output and mineral consumption for 1928 and 1937 are taken to represent two points on a linear relation (the strongly linear record of the same relation in American experience makes this assumption not implausible), then each per cent increase in mineral consumption tended to be accompanied by 0.93 per cent, or nearly as much, increase in gross industrial output. Should the same linear relation continue to hold, then its "elasticity" at successively higher values of mineral consumption must gradually approach unity. Industrial output may be related to mineral consumption in two other ways: in terms of the "value ratio," i.e., the ratio of the gross value of industrial output to the value of minerals consumed by the economy in the same year (or other time period); and the "incremental-value ratio," or the ratio of the *increment* in one series to the *increment* in the other. The value ratio declined moderately from 22.4 in 1928 to 19.0 in 1937, i.e., the series in the denominator grew somewhat faster than the series in the numerator, a partial reflection of the rising average mineral-intensity of Soviet industrial output (see below). Should the same linear relation continue to hold — a somewhat speculative assumption — its value ratio will slowly move toward an asymptotic value of 17.7, the incremental-value ratio. That is obtained by dividing $11.9 billion (at 1937 U. S. prices), which is the increase in the gross value of Soviet industrial output between 1928 and 1937, by $674 million, the increase in the value of mineral consumption over the same period. In other words, it shows that each *additional* dollar's worth of mineral consumption tended to be associated with almost eighteen dollars' worth of *additional* gross industrial output.

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* For a complete discussion see Grossman and Shimkin (1952). The official Soviet claims are an increase of 5.29 times in the output of large-scale industry (Ioffe, 1939, p. 2); for all industry, 4.38 times (Jasny 1950, p. 95), and for all industry 1937–40, 45%. For critiques of these claims see Gerschenkron (1947, *passim*); Jasny (1947, 1950); Hodgman (1950, p. 329); Bergson (1950, pp. 237–8).

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The somewhat faster growth of Soviet mineral consumption than industrial output, mentioned earlier, is not surprising. True, the more efficient use of fuels, the wider utilization of ferrous scrap, and the increasing "degree of fabrication" in certain industries tended to accelerate the increase of industrial output relative to the input of minerals in the economy. On the other hand, the Soviets stressed the expansion of capital-intensive, power-intensive and heavy metal-using industries. The share of mineral-intensive industries within all large-scale manufacturing, measured by an approximation of value added (labor and allied costs at 1934 ruble-cost level), rose from 32 per cent in 1927–28 to 50 per cent in 1937. "Mineral-intensive" industries here comprise petroleum refining, ferrous and nonferrous metallurgy, chemicals, coke, cement, glass, bricks, and machinery and metal working. The foregoing computation has been made from unpublished data kindly furnished by Dr. Donald R. Hodgman, and compiled by him for a forthcoming published version of Hodgman (1950).

In American experience, a 3.55-fold rise in mineral consumption took place over the considerably longer period between 1899 and the mid-twenties (see Appendix I, Sec. 1). During the same period,

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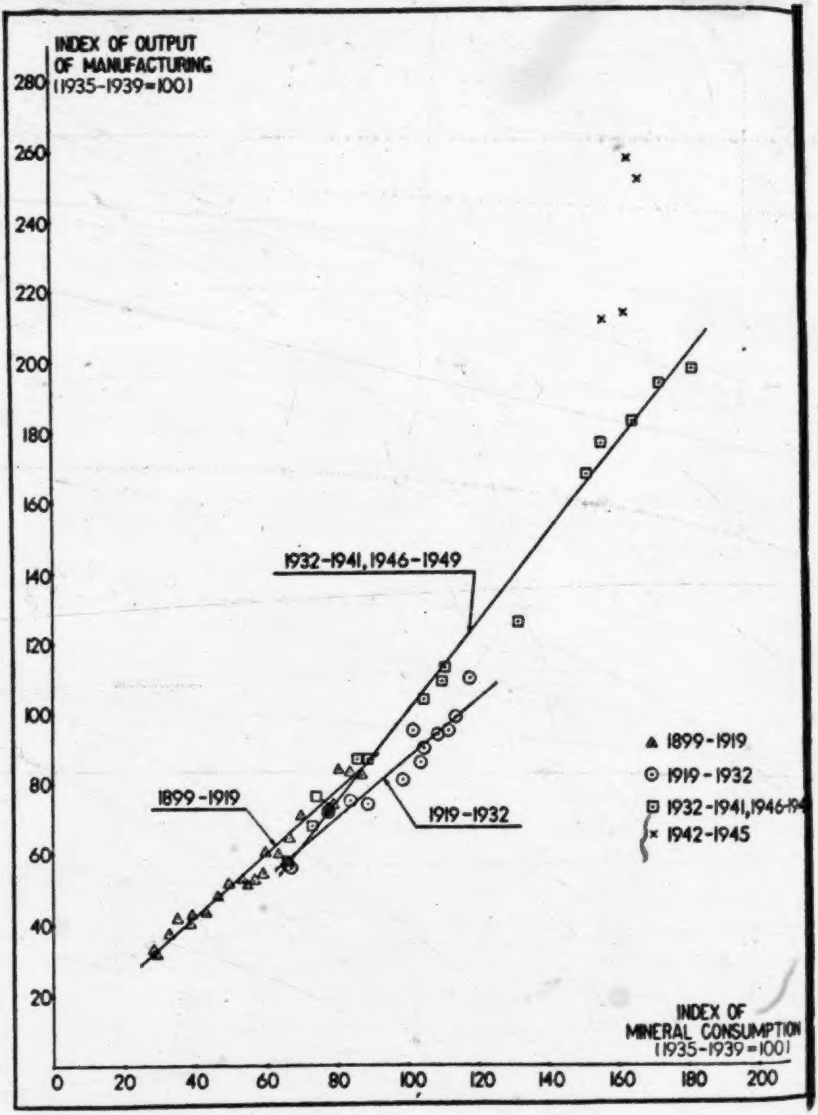

Figure 6
United States: Output of manufacturing and mineral consumption, 1899-1949

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the output of manufacturing (weighted by value added in manufacturing), which can be taken to approximate the movement of gross industrial output, rose almost exactly three times (Fabricant, 1940, p. 44). In this respect there seems to have been a close similarity between the experiences of the two nations. At the same time, examination of the American record for the entire period 1899–1949 reveals complexities not yet evidenced in the Soviet data. The same linear relation does not appear for the entire span 1899–1949; rather, three distinct subperiods, each with a rather low scatter around a discrete linear relation, are in evidence (Fig. 6). As a result of these "breaks" between the subperiods, the value ratio of gross industrial output to mineral consumption in the United States shows a U-shaped record over the whole half century, starting at over 18 in 1899, sagging to 14 (and just under) in the period between the First World War and the Great Depression, and recovering to almost 18 once again after the Second World War. A significant cause of the sag in the value ratio in the United States may have been the increasing importance of the mineral-intensive industries and the rapid expansion in petroleum refining for automotive transportation during the 1920's, followed by what appears to be a structural change in the economy at the bottom of the Great Depression. Yet there appears also to have been a convergence of the American and Soviet value-ratio trends, the first rising since 1932, and the second falling, at least since 1928. The significance of this convergence is not altogether certain. One factor appears to have been the growing similarity in the "product mix" of industrial output in the two countries, as indicated by the fragmentary evidence of the ratios between mineral-intensive and mineral-nonintensive industries in the total value added by manufacturing. At the same time, it is important to note that the mineral-consumption data from which the value ratios have been derived refer to consumption *by the whole economy* in both instances. The actual proportions consumed *by industry* are not known, but have prob-

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FIGURE 6

United States: Output of manufacturing and mineral consumption, 1899–1949

316 ably been higher in the Soviet case than in the American, for each
433 year considered, thus intensifying the degree of convergence.

It should be noted that the incremental-value ratio achieved by Soviet industry between 1928 and 1937 considerably exceeded the American performance — between 12 and 14 — before 1932, though it was less than the figure, 20, which seems to have held quite consistently in the United States since 1932 (excluding the unreliable war years). This high ratio despite large known waste in Soviet industry might be ascribed to economies achieved through extreme simplification, limited diversity, and minimal model change in manufacturing (see also Shimkin, 1948, 1950*a*).

000 The value ratios and the incremental value ratios for the United States, 1899 to 1949, were obtained as follows. The *incremental value ratios* are the slopes of regression lines (for the three subperiods indicated above) of a series representing industrial output (taken as the dependent variable) on our Index of Mineral Consumption (see Chapter II; U. S. values 1899–1949, given in Appendix I, Sec. 1). The series representing industrial production was obtained by splicing Fabricant's Index of Physical Output of Manufacturing Industries (Fabricant, 1940, p. 44) over the years 1899 through 1919 with the manufacturing component of the Index of Industrial Production of the Board of Governors of the Federal Reserve System, 1919–1949. The years of the Second World War — 1942–1945 — were omitted from the regression as clearly deviant from an otherwise strongly indicated correlation. The *value ratios* are simple ratios of the values of the two series for the individual years.

However, both index series were converted from the base of "1935–1939 average" to the corresponding absolute values in terms of the 1937 price level, so as to indicate the actual "input-output" relation in terms of an absolute and stable price level. Thus, one index point of the Index of Mineral Consumption was taken to be equivalent to $35.6 million at 1937 prices, which is the actual value obtained in the process of constructing the index. One index point of the gross industrial output series was taken to be equivalent to $570 million at 1937 prices, derived from the sum of the gross value of the products of manufacturing as shown in the 1937 Census of Manufactures (Bureau of the Census, 1940, p. 19) and the gross value of the products of mining in the same year (Barger and Schurr, 1944, p. 307), after elimination of certain minor duplications

49: Shimkin E-4 (no-date) 1953 R1 Soviet Union R1

in coverage between the two. (See also Grossman and Shimkin, 000 1952.)

Extrapolation to 1940 and 1950. In extrapolating past 1937 it 433 seems most proper to use the incremental-value ratios, which appear, in general, to have obtained between 1928 and 1937. This need not implicitly assume an invariant "technological" relation between the value of additional minerals consumed and the increments in the value of industrial output. But it is assumed that such changes as the incremental-value ratio may undergo with time — changes due to shifts in the composition of final output, methods of production, or efficiency of utilization of materials and fuels — are in part mutually offsetting, and in any case may not operate quickly enough to make the whole procedure entirely meaningless.

That simple straight-line extrapolation is fraught with numerous possible pitfalls and is at best a search for rough approximations in any economy and for any period need hardly be underscored. For the Soviet Union the reliability of even the base-period estimates is imperfect. Furthermore, the country has been undergoing a rapid economic and technological transformation, and has suffered the wreckage and stresses of the Second World War. In the light of all this, the justification for such a procedure rests chiefly on the severe paucity of postwar information and the consequent desirability of marshaling all available evidence for an understanding of the postwar economic picture. Of course, the estimates presented in Table 84 are only tentative figures, to be checked against possible parallel estimates of independent students, and to be retained, amended, or discarded, as additional evidence may be brought to bear on the subject.

The year 1950 has been selected as the postwar year to which the extrapolations are made. Not only does it evoke interest as the terminal year of the Fourth Five-Year Plan, but it is also at least as promising statistically as the preceding postwar years. The published Five-Year Plan targets referred to 1950, and official statements, though in the usual scanty and equivocal fashion, have been made regarding the purported attainment of the targets (Bulganin, 1950; *Pravda,* 17 April 1951).

The extrapolated estimates for 1940 and 1950 (at 1937 U. S. prices) are shown in Table 84; they refer to the U.S.S.R. in the boundaries of the respective years. The increase in gross value

433 of industrial output by 1950 so obtained is nearly fivefold in comparison with 1928 and 60 per cent in comparison with 1937. If weighting by some Soviet value system rather than by the American one had been used, the increase might have been appreciably different and most likely higher, though one cannot see how any meaningful weighting system can yield the increase in industrial output claimed by official Soviet sources. For instance, our estimates show a 45 per cent increase in industrial output between 1940 and 1950, compared with a 48 per cent increase (in terms of the so-called 1926–27 prices) targeted by the Fourth Five-Year Plan, and the 73 per cent (at the same prices?) increase claimed to have been achieved (Bulganin, 1950; *Pravda*, 17 April 1951). However, even if the official statements with respect to the 1950 output (relative to that of 1940) for separate branches of industry and for individual commodities are accepted at their face value, a 45 per cent increase in the output of industry as a whole seems to be much more plausible than the claimed 78 per cent rise. In fact, these statements claim more than *50 per cent* in but three branches: coal, chemicals, and machine building. *Pravda* (17 April 1951) includes claims for the following *increases* for 1950 over 1940 output: ferrous metals, 45 per cent; coal, 57 per cent; petroleum, 22 per cent; machine building, 130 per cent; chemicals, 80 per cent; construction materials, "more"; light industry (including textiles), 17 per cent; paper, 47 per cent; all local industry and coöperatives, 50 per cent. There may be an inclination to publish the more favorable figures; in addition, inflationary biases within some of these sector figures are probable, machine building being especially suspect in this regard because of past record.

489 *Mineral Consumption and Transportation.* Because minerals comprise a large proportion of freight and transportation absorbs a
316 major fraction of the national mineral input, especially fuel, we should expect close correspondence between indexes of mineral consumption and the volume of transportation. Soviet experience between 1928 and 1950 corroborates this view (see Table 84). Domestic transportation is here the total freight ton-mileage of Soviet railways, river transport, and (after 1934) automotive road transport. A large omission is the transport with animal draft power, on which no data are known to exist; others include pipelines and maritime cabotage, for which consistent series over the period are

not available, as well as air transport and automotive road trans- 489
port (1928 through 1934), which could affect the index but negligi- 316
bly in any case.

The mineral-consumption and transportation series virtually coincide except for lags in the transport series in 1934 and 1947. The former year is known to have witnessed a serious "transport crisis"; there have been indications of a transport crisis in 1947 as well. Postwar data on transportation appear to rest on more dependable statistical information than do the estimates underlying our index of mineral consumption. The fact that the close correspondence between the two series continues into the postwar years may perhaps be taken as an indication that the mineral-consumption estimates for those years are not unreliable. This opinion gains corroboration from the finding that American experience between 1920 and 1940/46, the only period for which data are available, also shows an extremely close correspondence between movements in the Index of Mineral Consumption and an index of the aggregate freight ton-mileage of steam railroads, intercity motor trucking (for hire and private), pipelines, and coastal, intercoastal, Great Lakes, and inland waterways (Grossman and Shimkin, 1952; Barger, 1951, pp. 184–185, 242, 251, 254).

At the same time, while the movement of domestic transportation volume in relation to mineral consumption appears to have been identical in the two countries, the *absolute level* of transport ton-mileage per index point of mineral consumption has been 40 per cent higher in the U.S.S.R. than in the United States. (The ratio for the latter is 6.64 billion short-ton-miles per index point, that is, per $35.6 million worth of mineral consumption at 1937 prices.) The underlying reason for this phenomenon has been the failure of the Soviet Union to emulate the American shift from solid to higher-caloric, more easily transportable, liquid and gaseous fuels.

The Structure of Consumption. The secular trends in the structure 433
of Soviet mineral consumption were profoundly disrupted by World 328
War II, but have reappeared since then. In contrast to American
experience since 1899, they manifest a growing share for ferrous 327
metals, a declining one for fuels. Soviet peacetime trends in nonferrous-metals consumption as a whole correspond to the American record since 1919; so also do nonmetallics, if 1926 is excluded. In the war year, 1944, the Soviet consumption of nonferrous metals

433 — particularly Lend Leased aluminum and copper — was relatively
328 very high; that of fuel, extremely low (cf. Appendix I, Sec. 1).
Specifically, the structure of the Index of Mineral Consumption has
327 varied, between 1926 and 1950, in the manner shown in Table 85.

What has been the behavior of individual minerals in relation to the movements of the Index of Mineral Consumption? Among metals, pig iron, manganese, copper, and zinc have advanced in fair correspondence to the Index. However, the consumption of aluminum, nickel, and various "new" metals such as cadmium has grown much more rapidly; that of tungsten, lead, tin, mercury, and probably antimony, more slowly. Among fuels and other nonmetallics, the growths of natural gas, coal, asbestos, and gypsum appear to have approximated the average trend. Diamonds, fertilizers, sulfur minerals, and high-grade refractories such as magnesite have moved more rapidly, while the consumption of petroleum, salt, and clays seems to have lagged.

TABLE 85

Structure of Soviet mineral consumption, 1926–1950

Group of Minerals	*Percentage of Consumption (1937 U.S. prices)* 1926	1937	1944	1947	1950
Ferrous metals[a]	24.6	32.2	21.7	24.0	26.8
Nonferrous metals[b]	8.8	10.7	27.0	12.3	13.2
Fuels[c]	56.7	49.6	47.8	57.4	51.7
Other nonmetallics[d]	9.8	7.4	3.5	6.2	8.2

[a] Pig iron, spiegeleisen, ferromanganese, ferrosilicon, and half of nickel.

[b] Aluminum, copper, lead, half of nickel, tin, and zinc.

[c] Coal, lignite, natural gas, and petroleum.

[d] Asbestos, cement, industrial diamonds, calcined gypsum, salt, sulfur, and pyrite.

Sources: Appendix II; for methods, Chapter II.

135 Assessment of the adequacy of Soviet mineral supplies is a
433 difficult problem; to attack it, three lines of approach are open:
comparisons of Soviet consumption with production goals, comparisons with normalized American consumption trends, and consideration of special factors affecting Russian requirements. The use of Soviet production goals as criteria of self-sufficiency may be regarded as essentially valid, for this has been explicitly a basic aim of Russia's plans. At the same time, those minerals which have been produced in large degree for export, namely, manganese, asbestos,

and, for 1932, petroleum, must be excluded. In addition, since the 135
Fourth Five-Year Plan targets reflected not only production ambitions but adjustments to war-reduced capacities, it seems appropriate 433 to select the highest output figures designated in either the Third or the Fourth Five-Year Plans as points of reference. With these adjustments, the relations of actual to presumed target consumptions approximated 70 per cent in 1932, 80 per cent in 1937,

TABLE 86

Actual consumption of minerals as percentages of output goals, First, Second, and Fourth Five-Year Plans

Actual Consumption (per cent of output goal)	*1932*	*1937*	*1950*
> 120	—	Nickel, copper, potassium salts	—
95–110	Natural gas	Chromite, barite, china clay, gypsum	Copper, zinc, coal and lignite, cement
70–90	Coal and lignite, petroleum, salt	Zinc, pig iron, coal and lignite, natural gas, cement, sulfuric acid, soda ash	Aluminum, pig iron, petroleum, superphosphates, potassium salts(?), sulfuric acid, salt
40–65	Copper, pig iron, cement, sulfuric acid	Aluminum, petroleum, superphosphates, salt	Soda ash
< 40	Zinc, superphosphates	—	Natural gas

and 100 per cent in 1950. The patterns for individual minerals shifted in the manner shown in Table 86 (see also Tables 78, 79, and 87, and Appendix II).[1]

Comparisons with American experience may be made at two 433
levels: for mineral consumption as a whole, and for individual 327
minerals. The more general comparison has been dealt with. Here, 328
it suffices to say that Soviet miner[illegible]onsumption in the prewar period and, by extrapolation, in 1950, was low by American standards, relative to the sizes and rates of growth achieved in that

[1] [See Cat. 116, pp. 304-305, 307, 382-383, 385-391 --Analyst]

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49: Shimkin E-4 (no date) 1953 RI Soviet Union RI

TABLE 87

Estimated consumption of individual minerals, physical and normalized

Mineral	Consumption in Physical Units[a]					Consumption as Percentage of Hypothetical Standard[b]					
	1926	1937	1944	1947	1950	1926	1937	1944	1947	1950	
										P[d]	W[e]
Group A[c]											
Metals											
Antimony	0.8	2.6	2.5	4.0	x	150	65	83	135	x	x
Mercury	0.14	0.3	x	x	x	270	105	x	x	x	x
Copper	28.7	161	268	176	272	87	90	137	90	92	75
Lead	23.2	87.7	75	90	143	77	90	76	89	94	77
Tin	2.1	11.3	9	8	10.5	60	63	100	100	69	69
Zinc	16.6	77.2	90	85	142	71	63	84	66	73	[g]
Aluminum	1.8	40.2	255	90	180	43	89	270	112	147	100
Nickel[f]	0.02	9.7	11.3	11.6	.20	2	91	70	96	100	60
Pig iron (10^6 m.t.)	2.22	14.0	8.0	11.1	18.9	119	194	106	127	154	134
Fuels											
Coal, lignite (bitum. equiv., 10^6 m.t.)	24.1	115	108	164	241	93	112	130	181	176	153
Petroleum (10^6 m.t.)	6.66	26.8	19.5	28.9	35.0	126	70	61	63	50	[g]
Natural gas (10^9 m^3)	0.23	1.98	1.0	2.1	2.6	13	12	7	10	8	[g]
Nonmetals (10^6 m.t.)											
Salt	1.62	3.5	2.0	3.0	3.0	500	170	100	122	105	105
China clay	0.18	0.29	?	?	x	590	160	?	?	x	x
Gypsum	0.29	1.2	0.3	0.9	2.0	107	107	60	70	100	[g]
Phosphate rock	0.11	2.1	0.4	x	3.0	160[h]	300[h]	60[h]	x	175	[g]
Asbestos	17.3	58.8	35	66	143	160	87	72	72	100	[g]
Sulfur, pyrite (S content)	65	617	445	600	900	83	115	93	99	95	[g]
Diamonds (10^3 carats)	—	25	450	200	300	—	5	25	30	30	10

49: Shimkin E-4 (no date) 1953 RI Soviet Union RI

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TABLE 87 (Continued)

Mineral	Consumption in Physical Units[a] 1926	1937	1944	1947	1950	Consumption as Percentage of Hypothetical Standard[b] 1926	1937	1944	1947	1950 P[d]	1950 W[e]
Group B[i]											
Manganese ore ([illegible])	0.3	1.5	x	x	x	450	265	x	x	x	x
Tungsten (60% WO_3)	0.7	3.0	5.5	2.5	x	345	130	210	160	x	?
Molybdenum (content)	.006	1.4	1.2	0.9	?	18	60	60	45	?	?
Fireclay	749	2500	x	x	x	520	250	x	x	x	x
Andalusite	—	1.0	3.0	?	?	—	74	117	?	?	?

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[a] In thousands of metric tons, except as indicated.

[b] Normalized to U.S. consumption for the same years; cf. notes c, d, e, and i.

[c] Normalized to U.S. consumption at an Index of Mineral Consumption level of 100; cf. App. I, Sec. 1.

[d] Peacetime basis normalized to U.S. consumption in 1947; cf. App. I, Sec. 1.

[e] Wartime basis normalized to U.S. consumption in 1944; cf. App. I, Sec. 1.

[f] Excluding the nickel content of naturally alloyed pig iron.

[g] Wartime rate lower than peacetime.

[h] Note, however, the relations to the U.S. as inputs per cultivated acre: 1926, 5 per cent; 1937, 77 per cent; 1944, 10-12 per cent; 1950, 40 per cent. Includes, for the U.S.S.R., superphosphates (18.5 per cent P_2O_5) and ground phosphate rock.

[i] Steelmaking basics, normalized to pig-iron consumption in the United States; cf. App. I, Sec. 1.

Sources: Chaps. III–VIII; Appendix I, Sec. 1; Appendix II.

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country's gross industrial output and "gross national material product" (Soviet-concept GNP). In part, this has reflected structural differences between the two economies, especially the greater importance for Russia of agriculture and other nonmineral-intensive sectors. But, to an appreciable degree, skimping or even doing without have been evident in the Soviet economy, as the remarks on materials control will detail.

The general structural differences between the mineral-consumption patterns of the Soviet Union and the United States have already been mentioned. Table 87 provides more detail. It shows that, in 1928, Soviet metals consumption was relatively low, except for mercury, antimony, and pig iron. High petroleum consumption — even by American standards! — moderately low coal consumption, and negligible natural-gas consumption were also characteristic. The pattern for nonmetallics included very high salt and china-clay and high asbestos and phosphate-rock consumption, relative to the Index of Mineral Consumption. Sulfur and pyrite utilization was low; that of industrial diamonds, absent. In the group of steelmaking basics, normalized to pig-iron output, all but newly introduced molybdenum were marked by very high consumption.

By 1937, a marked convergence toward American practice had taken place. Excluding bromine, diamonds, natural gas, and several rare metals, the consumption of no mineral was now less than 40 per cent of Hypothetical Standard, while only magnesite, emery, and corundum exceeded this standard by more than 200 per cent (see Chap. II, and Appendix I, Sec. 1). Thus, the structure of Soviet mineral consumption in 1937 corresponded more closely to American than did either the German or the British of that period (see also Table 5). At the same time, except for soaring pig iron and mercury, metals consumption was low. In fuels, coal and lignite rose sharply, while petroleum fell to a low level; natural gas remained negligible. Convergence toward American practice was notable in other nonmetallics and steelmaking basics, although phosphate-rock consumption climbed to a very high level, and molybdenum utilization was still slight.

An essentially similar relation to the American wartime pattern persisted through World War II, except that nonmetallics dropped to low levels, even for a wartime period. Furthermore, a heavy military effort required, and Lend Lease shipments permitted, very high

aluminum and copper consumption. In contrast, the upward devi- 433
ation of pig-iron consumption from American practice was reduced 328
by heavy losses of capacity. 327

So far as is known or can be approximately guessed, the structures
of Soviet and American mineral consumption have changed in corre-
sponding manners in the postwar period too. The principal relative
changes between 1937 and 1950 have been strengthenings of Soviet
aluminum, antimony, coal, and lignite consumption, and reductions
in pig iron and nonmetallics, the latter now being generally at low
levels. The Soviet consumption pattern in 1950 apparently corre-
sponded to peacetime needs; for full-scale mobilization, the current
supply of nonferrous metals, especially, seemed scanty.

Beyond the comparisons with Soviet production goals and with 433
American practice, consideration must be given to four factors
basically affecting Russia's needs for minerals. The first is the large
scale of the country's agricultural requirements. It should be noted [162]
that the population of the Soviet Union has climbed from 147 mil-
lion persons in 1926 to 170 million in 1939 and, with territorial
acquisitions, to 193 million in 1940; 201 million in 1950 (Lorimer,
1946, pp. 112, 184–190; for 1950, approximated from electoral-
district data, cf. *Pravda*, 12 January 1950). Acreage under cultivation [311]
has likewise increased: 285 million in 1927–28, 334 million in 1937,
and some 363 million in 1950, compared to an average of 350 million
acres for the United States in recent years (Jasny, 1949, p. 503; for
estimated acreage actually cultivated in 1950, see Volin, 1951,
p. 187). At the same time, the catastrophes of collectivization and [231]
of World War II drastically cut the numbers of horses and other
livestock. Thus, in 1927, farm livestock totaled 30.8 million horses,
66.4 million cattle, 132 million sheep and goats, and 22.6 million
hogs. By 1932, the corresponding figures were only 19.6, 40.7, 52.1,
and 11.6 millions, respectively. In January 1941, livestock other than
hogs, even including gains from seized territories, were still far
fewer than in 1927: 21.3 million horses, 55.1 million cattle, 91.8
million sheep and goats, and 28.2 million hogs. A decade later,
the 1941 figures had been barely recovered; Russia's farms held
but 13.7 million horses, 57.2 million cattle, 99 million sheep and
goats, and 24.1 million hogs (Jasny, 1949, p. 797; for 1950, *Izvestiya*, 433
17 April 1951). Jasny's conclusion that the Soviet investment in 241
agriculture prior to World War II barely offset the losses in tractive 387

241 power and fertilizer resulting from livestock reductions may in large
387 part be applied also to more recent years (Jasny, 1949, esp. pp. 457–
433 460). In all, the healthy development of Soviet agriculture requires enormous quantities of fertilizers, sulfur minerals, and salt, and, for mechanization, large amounts of petroleum products and metals. For these minerals, Soviet plans seem to have understated the country's needs. True enough, man-year productivity in agriculture has grown, over the past quarter century, at a rate comparable to the ones achieved in mining and manufacturing (Shimkin, 1951). But crop yields have remained stagnant; only for cotton have post-war (1947–1949) Soviet yields per acre been significantly above the 1925–1928 averages (cf. Volin, 1951, pp. 114–135; and Central Statistical Administration, 1929, pp. 180–219).

162 The second factor has been Russia's rapid rate of urbanization and, consequently, of increase in demands for housing and utilities, since
339 1926. Her urban population grew from 26.3 million persons in 1926,
369 to 55.9 million in 1939, and about 68 million, including annexed
433 territories, in 1950 (Lorimer, 1946, p. 154; for 1950, estimated from *Pravda*, 12 January 1950, and politico-administrative maps). In the United States, the achievement of a comparable increase, from 30 to 74 million urban dwellers, extended from 1900 to 1940. Because of this factor, Soviet needs for cement, gypsum, asphalt, asbestos, ground mica, and salt (via soda ash for window glass), and for base metals, have been unusually great.

433 The heavy load of armaments carried by the U.S.S.R. since the
722 mid-1930's has also affected the structure of mineral demand Judging by American experience, this factor has doubled or more the needs that might otherwise exist for piezoelectric quartz crystals, industrial diamonds, beryl, tantalum, andalusite, aluminum, and tungsten. It has substantially raised demands for manganese, molybdenum, corundum, bromine, niobium, and cobalt, and, to a lesser degree, for pig iron, copper, strontium, arsenic, and coal (see Appendix I, Sec. 1).

433 The fourth and final factor has been the high losses in production, short equipment and product life, and limited use of scrap characterizing Soviet manufacturing, especially prior to World War II (see Tsar'kov, 1940; Shimkin, 1948).

To summarize the impressions gained from these three approaches to the problem of the adequacy of Russia's mineral supplies:

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(1) Total mineral consumption has been definitely low in relation 433
to imputed demand, throughout the past twenty-five years. 135

(2) Within this framework of an over-all shortage, considerable shifts in the relative adequacy of supply of individual minerals have taken place. Nonferrous-metals supplies as a whole have remained tight, but aluminum and copper, for *peacetime* requirements, are much less so than in the past. With some exceptions, such as molybdenum and cobalt, the U.S.S.R. has been characterized by a high consumption of pig iron and other steelmaking basics. In fuels, natural-gas consumption has remained virtually negligible, but coal and lignite have shifted from a weak to a strong position; petroleum from strong, to very weak. In other nonmetallics, Soviet consumption has generally grown too slowly. Considering Russia's enormous agricultural requirements and acute need for housing, the consumption of nonmetallic minerals, particularly fertilizers, sulfur minerals, and salt, has been very low since 1937.

(3) As mentioned under Foreign Trade, the scales of Russia's 439
mineral imports in the postwar and late prewar periods have been roughly comparable. On the other hand, the composition of imports has changed radically. In the earlier period Soviet imports were limited essentially to nonferrous and ferroalloying metals; postwar, fuels have predominated. Furthermore, the major sources of imported supplies have shifted from the United States, United Kingdom, and Germany, to Russia's Eastern European and Far Eastern satellites. At the same time, a few minerals, especially copper, diamonds, and tin, still flow in from areas outside of Soviet control.

(4) The large stockpiles of deficient nonferrous and ferroalloying metals built up between 1937 and 1939 were reconstituted through Lend Lease aid by the end of World War II. Their augmentation is unquestionably continuing. Their existence greatly reduces the economic hazards to the Soviet Union that might be developed by mobilization.

How has the Soviet government met the problem of perennial 135
shortages in minerals? The three mechanisms of materials control 433
appear to have been highly selective allocation, intensification in the use of capacity, and substitution. Pricing has not been a significant agency for achieving materials control (see Table 4 and the associated discussion). The limited diversity of Soviet manufacturing permitted few economies through the standardization and simplifi-

433 cation of design, which had proved to be a major contributor to
135 American materials conservation during World War II (see Civilian Production Administration, 1947, esp. pp. 660–661). Evidence on comprehensive salvage and scrap-recovery programs is also lacking. (For an illustration of American practice, see War Production Board, 1942.)

327 Within the limits of available information, it appears that, over
328 the past fifteen years, the following economic sectors have received
highly preferential treatment in the allocation of minerals: the steel
433 industry, especially machine-tool manufacturing; electrical equipment, rubber, and aviation; and agriculture, particularly the production of fibers and sugar. The railroads and electric-power production seem to have held middle ranks in priority. Proportionally, the railroads have received large quantities of ferrous metals and coal, but their allocation of petroleum, copper, and, since the war, tin have been rigidly restrained. An exceptionally large part of Soviet coal consumption has gone to electric-power production, but the use of petroleum for this purpose has been restricted since the mid-1930's. The economic sectors of low priority have apparently included wire but not radio communications; the petroleum industry, starved for steel, sulfuric acid, and, before the war, barite; paints and pigments, allotted substantial quantities of zinc and china clay, but little or no cobalt, lead, talc, and titanium; and the cellulose, paper, textile, glass, and food-processing industries. Domestic consumption has, of course, fared worst of all.

496 Since 1928, the intensity of use in the Soviet railroads has been
increased enormously. Thus, the ton-kilometers of freight hauled per
433 kilometer of first-track line have risen from 2.0 in 1928 to 6.9 in 1937 and about 8.3 in 1950 (calculated from Garbutt, 1949, pp. 17, 81; Hunter, 1950, pp. 4–6; and *Izvestiya*, 17 April 1951). This more intensified use of the railroads was accomplished by concentrating investment on a very few key lines. It gained very sharp increases in the productivity of transportation workers, as measured by annual ton-mileage per employee, but resulted in effects adverse to the regional development of the economy. Differences in the quality of transportation available became an extremely important locational
322 factor (see also Chap. IV, Sec. 1). Another area of basic savings has
433 been in urban housing; per capita space fell from 6.0 square meters

in 1928 to about 5.0 in 1937, and 4.5 in 1950.* Evidence of attempted [362]
economies in plant expansion has also come to light. For instance, 433
the postwar machine-tool additions at the ZIS automotive factory in Moscow were simply jammed into an already crowded floorspace (see Shimkin, 1950*a*).

In substitution, the Soviet record has been uneven. Among the 327
illustrations of successful substitution has been the increasing use of 328
naturally alloyed (chrome-, nickel-, vanadium- or titanium-bearing) 433
pig irons in low-alloy structural steels. During World War II and since, the Soviets sharply reduced their demands for machining and, thus, a wide range of ferroalloys by substituting casting, including that of artillery shells and valves. Nickel and tungsten demands have also been held down by replacement with more readily available manganese, chrome, and vanadium, particularly for stainless steels, tank armor, and artillery-barrel liners. Following German practice, the Soviets have made large use of local, low-grade lignite deposits as fuels for central electric-power plants. In addition, coal brasses washed from lignite are now a major source of sulfur in the U.S.S.R. A final significant development has been the use of abundant natural sodium sulfate for the simultaneous manufacture of ammonium sulfate and soda ash (the Belopol'skii synthesis), replacing acutely scarce sulfuric acid.

In many other instances, however, substitutions have been achieved only at the cost of much poorer operating characteristics, shorter life, and other seriously adverse effects. Noteworthy failures have been the lavish use of carbon tool steels prior to World War II; the attempted replacement of cobalt, tungsten, and nickel by manganese and chrome in stellites and electrical-resistance wires; and the use of iron or copper-coated steel wires rather than conventional lines and cables in wire communications. Such expedients as the use of vehicular attachments to produce combustible gas from wood blocks or peat, the replacement of superphosphates by ground

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* Calculated from scattered data, esp. TsUNKhU 1932, p. 301. and 1935, p. 631, correlated with Dobb (1948, p. 286 n.), the latter being dated as 1937 from *Slovar' Spravochnik po Sots.-Ek. Statistike*, 1948, p. 351. For 1940, 5% was added to the 1937 figure; for 1950, reconstruction realized during World War II (Bergson *et al.*, 1949) and during 1946–50 (Bulganin, 1950) have been added. The figures are maximal, since no factor for deterioration in existing housing has been allowed.

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433 phosphate rock, or the substitution of tar paper for galvanized roof-
327 ing iron need no comment.

328 Interestingly enough, the Soviets appear never to have built up
significant industries for producing artificial abrasives, graphite, or
325 synthetic liquid fuels. As late as 1949, Soviet work on synthetic liquid
433 fuels appeared to be experimental, and devoted primarily to low-pressure, low-temperature hydrogenation, with the recovery chiefly of naphtha. (See, for example, Obryadchikov, 1949, pp. 43–49.) In addition, Soviet steel metallurgists appear, as late as 1947, not to have been using the concept of end-quench hardenability range which has so profoundly modified American practice, eliminating the necessity of close restrictions on chemical composition for many special steels (Agapov *et al.*, 1947; Zapffe, 1948, pp. 23–25).

4. *Reserves and Potentials*

135 So far as I can tell, no major region of the Soviet Union has yet been subjected to genuinely thorough geological study and prospecting, by means of surface mapping, drilling, and geophysical and geochemical techniques. In fact, only European Russia south of 62°N and excluding the high ranges of the Caucasus, the Urals between 50° and 62°N, and small eastern areas such as the Kuznetsk Basin in Western Siberia and the Fergana Valley in Central Asia, can be termed reasonably well known. For the rest of the country, present knowledge appears to grade from rough economic assessment to complete ignorance. Because of this fact, and because even the geological reconnaissances covering large areas have revealed extensive promising formations, a sharp distinction must be made between more or less known reserves and ultimate potentialities in assessing Russia's mineral wealth.

Generalizations based even on quantitatively assessed reserves must be viewed with great caution. The available information dates essentially from the late prewar period; the quality and certainty of the reserves fluctuate greatly. Reëxamination of early basic studies and collation of later information have been able to remedy these deficiencies only to a moderate extent.

The degree to which these known reserves may be adequate to satisfy foreseeable Soviet needs can, of course, be answered only in hypothetical form. This volume has adopted the following criteria of "sufficiency": the capacity to meet requirements to 1970 at an average Index of Mineral Consumption of 86 (twice that of 1950), without wars or intensive mobilizations during the intervening period, but with the maintenance of a mineral-consumption structure corresponding to an extrapolation (to 1960) of the American (see Chap. II; also Appendix I, Sec. 1). Under such conditions the following classification of minerals by reserve status may be made. (Wherever available, estimated *total* reserves in millions of metric tons are given in parentheses following the mineral. *The data cited are largely for the period 1936–1939.* For details, see Chaps. III–VIII.)

(1) *Large surpluses possible:* andalusite and related aluminum silicates (good to fair ore, 3.8; low grade, 65); asbestos (for fibers over 0.7 mm, 19.3); bromine (100); probably cerium and rare earths; china clay (535); fire clay (1,041); coal and lignite (about 1,000,000, of which some 20 per cent is lignite); fluorspar (13.6); graphite (largely amorphous, about 1,000); gypsum (3,000); iron ore (excluding ferruginous quartzites, 8,300; with an iron content of 3,600); micas; magnesite (250 to 630) and dolomite (over 74); magnesium salts (18,000); manganese ore (786); phosphate rock and apatite (over 9,000); potassium salts (18,500, K_2O content); salt (limitless); natural sodium salts — mirabilite (over 500); titanium (TiO_2 content of titano-magnetites, from 10.2 to 70); and vanadium. It should be noted that the Soviet satellites are lacking or very weak in andalusite and related aluminum silicates, asbestos, cerium and rare earths, the micas, phosphate rock, titanium and vanadium.

(2) *Safe supplies:* antimony (over 0.4); chromite (25 to 30); emery; probably iodine; mercury (over 0.020); petroleum (between 65 and 100 billion bbl total, although only 1.7 billion bbl operating reserves); platinum; and sulfur and pyrite (possibly 60 of native sulfur, though of low quality; about 50 of pyrite and sulfide tailings; over 200 of coal brasses). Of these minerals, all but antimony represent moderate to severe satellite deficiencies.

(3) *Doubtful adequacies:* arsenic; barite (5 to 10, plus 13 very conjectural); bauxite (41.5 including low grades; aluminum content, 10.0 to 10.7); beryllium; copper (18 to 20 million, including low-content ores); nickel (about 1.3, including Petsamo); and zirconium. The barite, bauxite, and possibly arsenic deficiencies can be met by imports from the satellites; beryllium is found in North

135 Korea in unknown but possibly substantial quantities. Copper, nickel, and zirconium resources are weak or lacking in the satellite regions.

(4) *Moderate to acute deficiencies:* bismuth, borax (B_2O_3 content, 0.24); cadmium (0.017, including submarginal sources); cobalt (under 0.025 in workable concentrations); corundum; diamonds; lead (4.1); molybdenum (about 0.030, maximum); natural gas (985 billion m^3); strontium (over 0.024); high-grade talc (low-grade reserves, 5.0; steatite, 245); thorium; tin (over 0.1); uranium (excluding very low-content ores); and zinc (5.8). Imports from the satellites could eliminate the talc and tungsten deficiencies, in addition to ameliorating those in bismuth, cadmium, lead, molybdenum, tin, uranium, and zinc. The satellite resources of the other minerals appear to be negligible.

In general, the mineral wealth of the Soviet Union, as presently known or inferred, approximates that of the United States (see Bureau of Mines and Geological Survey, 1948). Both countries have enormous reserves of coal and lignite, magnesium salts, and a series of nonmetallic minerals: bromine, fire clay, gypsum, phosphate rock, and low-grade sulfur basics. The known copper reserves are approximately equal, while neither has measurable resources of diamonds. Soviet reserves are much greater than those of the continental United States and Alaska for antimony, asbestos, possibly china clay, chromite, amorphous graphite, magnesite, manganese ore, mercury, mica, nickel, possibly petroleum, platinum, potash, natural sodium salts (mirabilite), and tin. On the other hand, the American potentials considerably exceed those known for the U.S.S.R. in bauxite, borax, cadmium, cobalt, fluorspar, helium, iron ore, lead, dolomite, molybdenum, natural gas, titanium (including titano-magnetites), tungsten, vanadium, and zinc.

The major differences between the Soviet Union and the United States in regard to mineral self-sufficiency are therefore not those of more or less ascertained physical endowment but rather of the probabilities of new discoveries, of the potential mineral-consumption requirements, and of the politico-economic *orientations*. Thus, while the finding of numerous new and rich deposits is very likely in the Soviet Union, comparable radical changes are improbable in the United States, with the notable exception of Alaska. Again, American mineral-consumption requirements between 1950 and 1970 may be

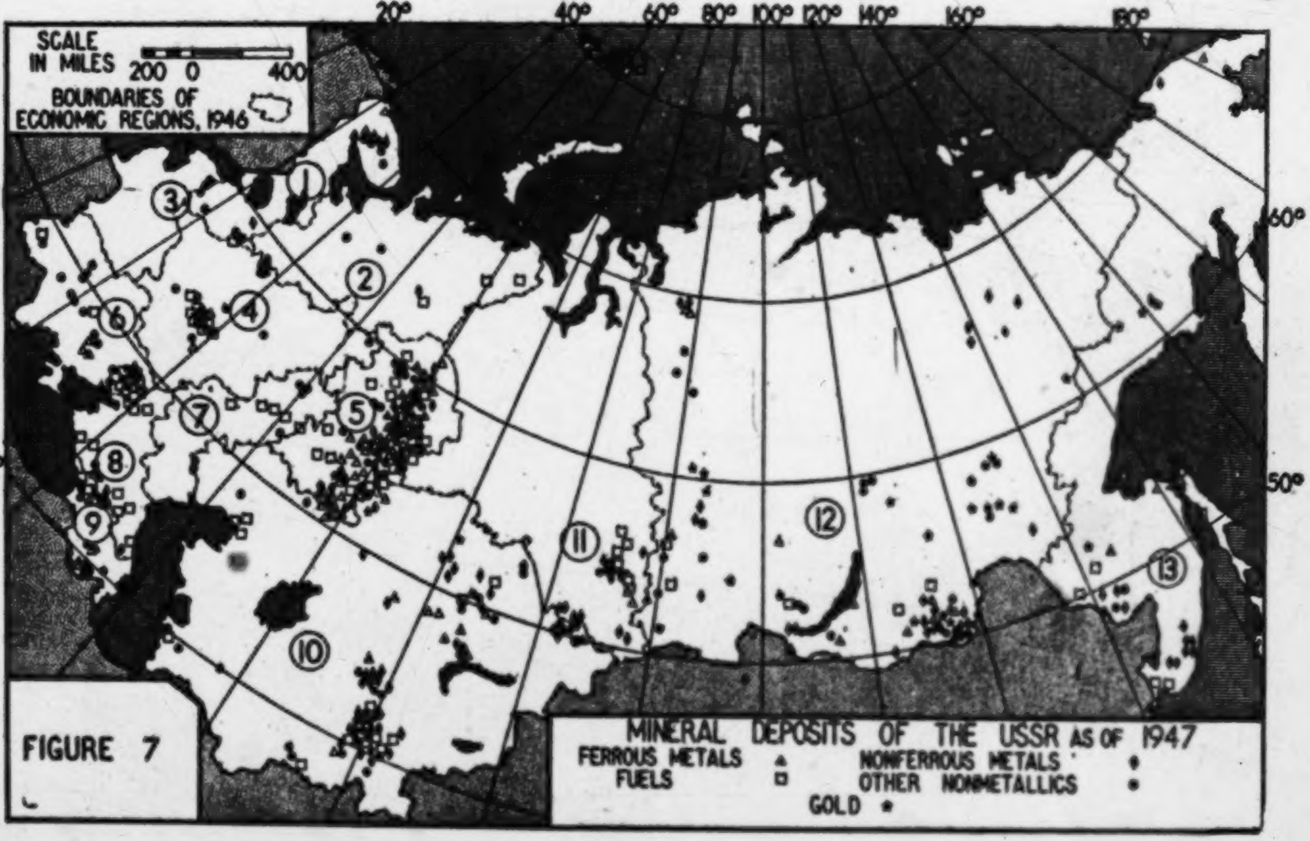
135

anticipated, even by a conservative extrapolation, to be 2.5 to 3 times those of the Soviet Union for the same period (see Appendix I, Sec. 1, and Table 83). Finally, and above all, the Soviet Union has attempted, and will presumably continue to attempt, to gain self-sufficiency without regard to production costs.

The known mineral resources of the Soviet Union are distributed very unevenly (see Fig. 7). For many minerals, the bulk of reserves is concentrated in but one to three deposits. In fact, by far the largest portions of the Soviet resources of bromine, magnesium salts, and potash are all contained in one deposit group, the Solikamsk-Berezniki district of the Urals. Similarly, Khaidarkan in Turkestan is at once Russia's predominant mercury, second-largest antimony, and largest, albeit low-grade, fluorspar deposit. Lovozero in North Russia has most of the nation's known reserves of cerium and rare earths, niobium and tantalum, as well as significant quantities of andalusite. Other minerals characterized by great geographical concentration include asbestos (largely Bazhenov, in the Urals), beryllium (Izumrudnye Kopi in the Urals; Sherlova Gora in Eastern Siberia), bismuth (largely Adrasman in Turkestan), borax (Inderskoye in Turkestan), chromite (largely Kempirsai in Turkestan; Sarany in the Urals), emery (largely Obukhovo in Western Siberia), diamonds (Krestovozdvizhinskii Priyisk in the Urals), iodine (Beyuk Shor in the Transcaucasus), magnesite (largely Satka in the Urals), dolomite (Nikitovka and Yama in the Ukraine), manganese (largely the Nikopol' group in the Ukraine; Chiatura in the Transcaucasus), muscovite mica (largely the Mama-Vitim group in Eastern Siberia), phlogopite mica (largely the Aldan group in Eastern Siberia), vermiculite mica (Buldymskoye in the Urals), natural sodium salts—mirabilite (largely Kara Bugaz in Turkestan), strontium (Priluk deposits in North Russia, Lyakan in Turkestan), steatite (largely Shabry in the Urals), and pyrophyllite (Suran in Turkestan).

In contrast to this long list of highly concentrated resources, a dispersed pattern, as evidenced by fifteen or more significant deposits, has been found for only eight minerals. They include bauxite, coal and lignite, copper, gold, gypsum, iron ore, lead, and petroleum. But the distribution of even these minerals is by no means uniform. In general, Russia west of 60°E has the overwhelming bulk of the country's gypsum, iron ore, and petroleum. The national coal and lignite resources rest, in a comparable proportion, east of this line.

49: Shimkin E-4 (no date) 1953 RI Soviet Union RI


SCALE IN MILES
200 0 400
BOUNDARIES OF ECONOMIC REGIONS, 1946
20°
40°
60°
80°
100°
120°
140°
160°
180°
60°
50°
40°
1
2
3
4
5
6
7
8
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10
11
12
13
MINERAL DEPOSITS OF THE USSR AS OF 1947
FERROUS METALS ▲
NONFERROUS METALS ◆
FUELS □
OTHER NONMETALLICS ●
GOLD ✱

FIGURE 7

135 Over two-thirds of Soviet copper and lead reserves are found in Turkestan; about four-fifths of Russian bauxite, in the Urals. In gold, Eastern Siberia and the Soviet Far East predominate. Obviously, the goal of self-sufficiency for many of Russia's present economic regions is a chimerical one.

The unevenness of mineral-resource distribution in the Soviet Union has been reflected in the great regional variations of mineral output shown in Table 80. In general, the shifts in production between 1926 and 1950 have corresponded increasingly with the pattern of known resources. Thus while the continued eminence of the Ukrainian area has been based solidly upon its great reserves of iron ore, manganese, salt, clays, and coal, the displacement of the Transcaucasus by the Urals has reflected the increasing exploitation of the

FIGURE 7

Mineral deposits of the U.S.S.R as of 1947

Economic Regions, 1946

1. Northwestern Russia*
2. Northern Russia*
3. Baltic (Western) Russia†
4. Central Russia*
5. Urals
6. Ukrainian (Southern)†
7. Volga
8. North Caucasus
9. Transcaucasus
10. Turkestan (Central Asia)†
11. Western Siberia
12. Eastern Siberia
13. Far East

Mineral Group

Ferrous Metals: Chromite, cobalt, iron ore, manganese, molybdenum, nickel, titanium, tungsten, vanadium

Nonferrous Metals: Antimony, arsenic, bauxite, beryllium, bismuth, cadmium, cerium and rare earths, copper, lead, mercury, niobium (columbium), platinum, thorium, tin, uranium, zinc, zirconium

Gold

Fuels: Coal, lignite, petroleum, natural gas.

Other Nonmetallics: Andalusite, asbestos, barite, borax, bromine, china clay, corundum and emery, diamonds, fluorspar, graphite, gypsum, iodine, magnesite and magnesium salts, mica (muscovite, phlogopite, and vermiculite), phosphate rock, piezoelectric quartz crystals, potassium salts, salt, natural sodium salts, strontium, sulfur and pyrite, talc.

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* "Russia" added for clarity.

† The official names (in parentheses) have been changed as shown to avoid confusion with noncomparable earlier regions with the same names.

49: Shimkin E-4 (no date) 1953 R1 Soviet Union R1

135 extraordinarily diverse resources of the latter region. The Transcaucasus is noteworthy largely for petroleum, manganese, and copper, while the Urals lead the country in asbestos, bauxite, beryllium, bromine, probably cobalt, magnesium salts, nickel, platinum, potash, pyrite, talc, and titanium reserves, and hold second place in chromite, copper, and iron ore. They are, however, weak in fuels, markedly so in coking coal. The rise of Turkestan is understandable in terms of this area's prominence in base metals, including copper, lead, zinc, antimony, and bismuth; in chromite, mercury, molybdenum, and uranium; in andalusite, borax, and sodium salts. In addition, Turkestan is strong in both coal and petroleum; the paucity of ascertained iron reserves is its greatest deficiency.

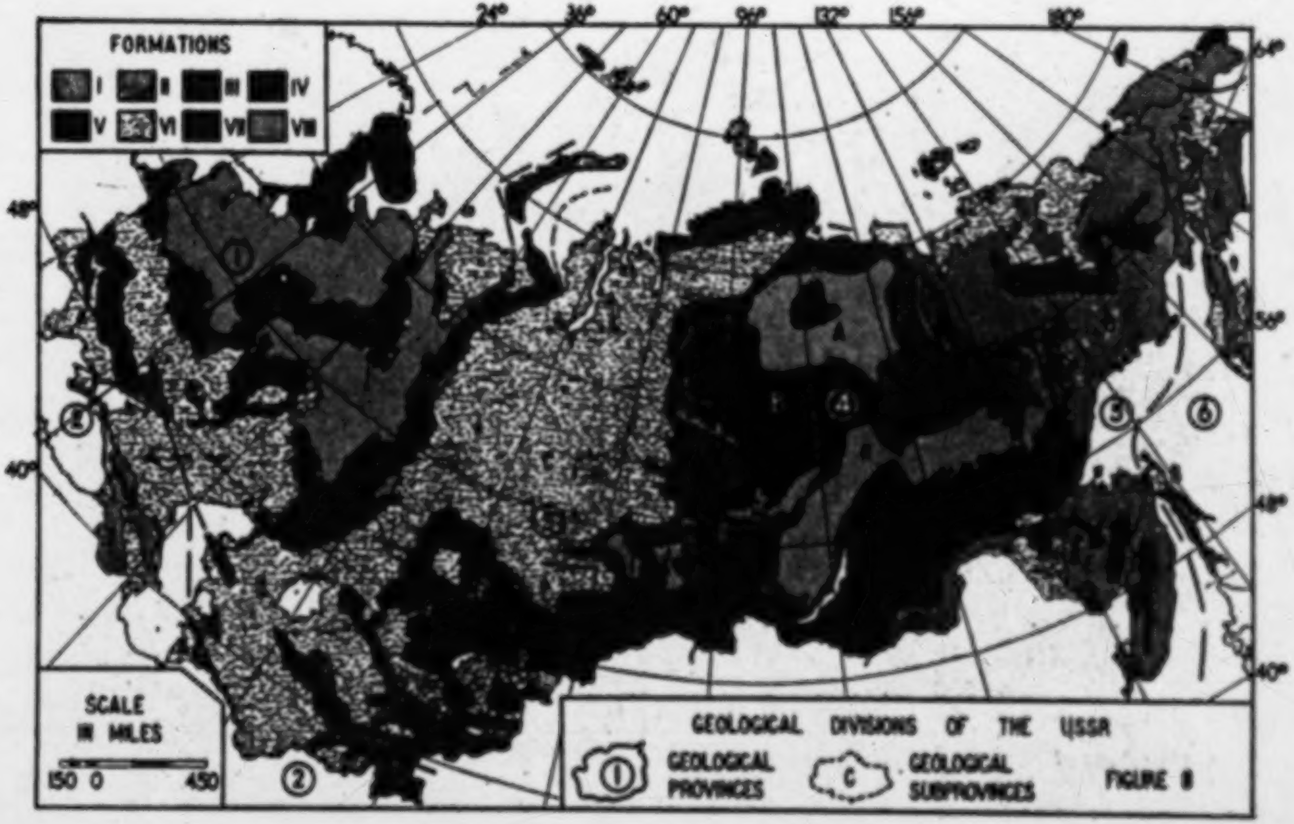
At the same time, we must emphasize that the correspondence between rank in reserves and rank in current production is still by no means complete. Eastern Siberia, which is first in coal and mica, and has strong reserves in numerous other minerals, is as yet a minor producer. Comparable discrepancies are even more notable for individual minerals. For instance, Kerch in the Crimea, though low in quality, is the country's largest iron deposit. Before World War II, its production was never significant; since then, it appears to have ceased altogether. The largest graphite deposit in the Soviet Union is the scarcely developed one at Soyuznoye, in the Soviet Far East. And barite, fluorspar, and vanadium provide still other illustrations. In all, the distribution of known resources foreshadows a continuation of the historic eastward shift in mineral production. Contrasting with the unexploited riches mentioned is the poverty in assessed mineral resources of the Baltic, Central Russian, Northwest Russian, and North Russian areas (excluding, in the last two areas, the metalliferous region of the Kola Peninsula and the Pechora coal basin, both north of the Arctic Circle).

Thus far, only the more or less determined mineral resources of the Soviet Union have been considered. But Russia, as was mentioned earlier, is still but little known geologically. Hence, attention must also be given to further, generalized indications of the country's potentialities. In order to gain such indications, Fig. 8 has been compiled. It represents the geological provinces and subprovinces, major formations, and associations of the Soviet Union in relation to known mineral deposition. It is noteworthy that many formations which have proved highly productive in relatively well-explored regions are also found in others still poorly known. The probability of mineral discoveries in the latter is therefore fairly high. For example, of the areas of Pre-Cambrian formation, the Azovo-Podol'sk and Baltic Shields, the Yenisei Ridge and the Eastern Sayan-Aldan Subsystem already have proved important, especially for iron ore, gold, mica, graphite, apatite, nickel, rare earths, and radioactive minerals. Additional discoveries in these regions are likely; so too are completely new finds in the scarcely explored Pre-Cambrian regions of the Caucasus, the Pamirs, the Kazakhstan Upland, the Taimyr Peninsula, and the Central Siberian and Bureya Uplands.

Again, the Urals are not unique. Closely similar regions of severe Paleozoic diastrophism with extensive acidic and basic to ultrabasic intrusion are the Kazakhstan Upland, the Angara-Yenisei Subsystem, and the Western Sayan Ranges. The first of these has already become predominant in copper; its areas of basic and ultrabasic intrusions promise well for current Soviet iron-ore prospecting. The other two regions have been barely explored. Yet it is not likely that the Noril'sk deposit, rich in platinum metals, copper, nickel and cobalt, in the Angara-Yenisei Subsystem, and Ak-Tovrak, second only to Bazhenov in asbestos reserves, in the Western Sayan Ranges, are unique.

Similar inferences might be drawn for areas of sedimentary deposition. The great bulk of known Soviet petroleum reserves are associated with limited areas of Cenozoic marine formation, largely near the eastern and western shores of the Caspian Sea. But these remnants of the Thetis Ocean and its successors extend in their entirety from the Ukraine across the North Caucasus and Lower Volga, into Central Asia, reaching the Arctic in Western Siberia. The fraction explored is indeed small.

It is essential to note that the data summarized in Fig. 8 are tenuous. The basic information is poor, so that even the broad delineations made are often questionable. For example, the Taimyr Peninsula has been classified with both the Urals-Tyanshan System and the Central Siberian Platform (Arkhangel'skii, 1941, pp. 97–107). Whether or not Pre-Cambrian formations constitute the core of the Urals is still a moot point. The terms necessarily used are excessively broad: "Pre-Cambrian," especially, is a geological grab bag. For the most part, the data given derive from surface reconnaissance only; the depths of formations and the characters of the


FORMATIONS
I
II
III
IV
V
VI
VII
VIII
24°
36°
60°
96°
132°
156°
180°
48°
40°
56°
①
②
③
④
⑤
⑥
SCALE
IN MILES
150 0 450

GEOLOGICAL DIVISIONS OF THE USSR

① GEOLOGICAL PROVINCES
C GEOLOGICAL SUBPROVINCES

FIGURE 8

FIGURE 8

Geologic provinces and mineral deposition

Major Formations

I. Mesozoic and Cenozoic diastrophism, with extensive lavas and acidic (granitic and syenitic) intrusions, rarely basic (dioritic).
II. Paleozoic diastrophism, with acidic intrusions.
III. Paleozoic diastrophism with extensive acidic and basic-ultrabasic (dioritic-peridotitic) intrusions.
IV. Pre-Cambrian shields, with extensive acidic and limited basic-ultrabasic intrusions.
V. Upper Permian–Lower Triassic lava beds and dikes
VI. Cenozoic sediments
VII. Mesozoic sediments
VIII. Paleozoic sediments
(VI–VIII) Undisturbed to moderately metamorphosed; no lavas or intrusions.

Provinces, Formations, and Associated Minerals

Province Subprovince	*Formation*	*Association*	*Known Deposits*
1. *Eastern European Platform*			
A. Baltic Shield	Pre-Cambrian	Ultrabasic intrusion	Cobalt, nickel
		Acidic intrusion	Andalusite, cerium and rare earths, iron ore (magnetite), niobium and tantalum, phosphate (apatite), titanium
		Metamorphic	Andalusite
B. Azovo-Podol'ak Shield	Pre-Cambrian	Acidic through basic	Piezoelectric quartz crystals
		Acidic intrusion	Zirconium
		Hydrothermal	China clay
		Metamorphic	Graphite, iron ore (hematite)

Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
C. Central Russian Plain	Paleozoic (Devonian-Permian)	Hydrothermal	Strontium, radium salts
		Metamorphic	Coal, iron ore (limonite)
		Sedimentary	Bauxite, borax, bromine, fire clay, lignite, gypsum, magnesium salts, manganese, petroleum, potassium salts, salt, sulfur
	Mesozoic	Sedimentary	Fire clay, phosphate rock, petroleum
	Cenozoic	Metamorphic	Lignite
		Sedimentary	Fire clay, salt
D. Donets Basin	Paleozoic (Carboniferous-Permian)	Hydrothermal	Antimony, Mercury
		Metamorphic	Coal
		Sedimentary	Dolomite, salt
E. Mangyshlyak Hills	Mesozoic	Metamorphic	Coal
2. *Alpine System*			
A. Central Asiatic-Black Sea Lowland	Cenozoic	Sedimentary	Iron ore (limonite), manganese, petroleum, potash, salt, vanadium
B. Caucasus Uplands (Cenozoic Diastrophism)	Pre-Cambrian	Hydrothermal	Cadmium, lead, zinc
	Mesozoic (primarily Jurassic)	Basic intrusion	Cobalt, iron ore (magnetite)
		Acidic intrusion	Copper, molybdenum
		Hydrothermal	Arsenic, barite, molybdenum, tungsten
		Sedimentary	Gypsum, manganese, salt

49: Shimkin E-4 (no date) 1953 RI Soviet Union RI

Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
C. Kopet Dag Uplands (Cenozoic Diast.)	Cretaceous-Pliocene	—	—
D. Pamir (Cenozoic Diast.)	Pre-Cambrian	—	—
	Paleozoic	Acidic intrusion	Piezoelectric quartz crystals
		Hydrothermal	Fluorspar
3. *Uralo-Tyanshan System*			
A. Paikhoi-Novaya Zemlya Subsystem (Upper Paleo. Diast.)	Paleozoic (Silurian-Permian)	Hydrothermal	Fluorspar
		Metamorphic	Coal
	Mesozoic-Cenozoic	—	—
B. Urals (Lower and Upper Paleozoic Diast.)	Paleozoic (?Pre-Cambrian-Carboniferous)	Ultrabasic intrusion	Asbestos, chromite, cobalt, iron ore (titano-magnetite), magnesite, nickel, platinum, vanadium (titano-magnetite)
		Basic intrusion	Cobalt, copper, iron ore (magnetite), pyrite, zinc
		Acidic through basic	Piezoelectric quartz crystals, vermiculite, mica, talc
		Acidic intrusion	Arsenic, barite, beryllium, china clay, corundum, gold, iron ore (magnetite), niobium, quartz crystals, titanium, zirconium
		Hydrothermal	Magnesite, tungsten
		Metamorphic	Coal, graphite
		Sedimentary	Bauxite, lignite, manganese, salt

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Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
C. Western Siberian Lowland	Mesozoic (Jurassic-Cretaceous)	Metamorphic	Coal, iron ore (limonite)
		Sedimentary	Bauxite, fire clay, lignite, manganese
	Cenozoic	Sedimentary	Salt, sodium salts
D. Central Asiatic-Black Sea Lowland	Mesozoic (Jurassic-Cretaceous)	Metamorphic	Coal and lignite
		Sedimentary	Barite, bauxite, gypsum, petroleum, salt, sodium salts (mirabilite), strontium, sulfur (native)
	Cenozoic	Sedimentary	Petroleum, salt, sodium salts, sulfur
E. Tyanshan Ranges	Paleozoic (including ?Pre-Cambrian), Upper Paleozoic diastrophism	Acidic intrusions	Andalusite, bismuth, copper
		Hydrothermal	Antimony, arsenic,† bismuth, cadmium, fluorspar, lead, mercury, tungsten, uranium,† zinc
		Metamorphic	Phosphate rock, vanadium
F. Karaganda Coal Basin	Paleozoic	Metamorphic	Coal
		Sedimentary	Fire clay
	Mesozoic	Sedimentary	Lignite

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Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
G. Kazakhstan Upland	Pre-Cambrian	—	—
	Paleozoic (largely undifferentiated and Silurian), Lower and Upper Paleozoic diastrophism	Ultrabasic-basic intrusions	—
		Acidic intrusions	Andalusite, copper, corundum, molybdenum, tungsten
		Hydrothermal	Copper, lead
		Unknown	Barite, iron ore, manganese, bauxite
		Metamorphic	Coal
		Sedimentary	Bauxite
H. Altai Ranges	Paleozoic (Undifferentiated and Silurian), Upper Paleozoic diastrophism	Acidic intrusions	Arsenic, emery, iron ore (magnetite), tungsten
		Hydrothermal	Barite, cadmium, copper, lead, mercury, molybdenum, zinc
		Sedimentary	Manganese, bauxite
	Cenozoic (lacustrine)	Sedimentary	Sodium salts (mirabilite)
I. Kuznetsk Coal Basin	Paleozoic (Permian)	Metamorphic	Coal
		Sedimentary	Fire clay
J. Minusinsk Coal Basin	Paleozoic (Permian)	Metamorphic	Coal
K. Chulymo-Yeniseisk Basin	Mesozoic (Jurassic)	Sedimentary	Lignite
L. Western Sayan Ranges	Pre-Cambrian–Paleozoic (Lower Paleozoic diastrophism)	Ultrabasic intrusions	Asbestos

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Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
M. Taimyr Peninsula	Pre-Cambrian	—	—
	Paleozoic (Silurian and Permian). Upper Paleozoic diastrophism	—	—
4. *Central Siberian Platform*			
A. Central Siberian Uplands	Pre-Cambrian	—	—
	Paleozoic (Cambrian-Permian)	Metamorphic	(Coal)
B. Tunguska Lava Beds	Upper Permian–Lower Triassic	—	—
C. Tunguska Basin	Paleozoic (Upper Carboniferous–Lower Permian)	Metamorphic	Coal, graphite
D. Lena-Khatánga Trough	Mesozoic (Jurassic-Cretaceous)	Sedimentary	Lignite
E. Angara-Yenisei Subsystem	Paleozoic (Cambrian-Permian) Lower and Upper Paleozoic diastrophism	Ultrabasic intrusions	Cobalt, copper, nickel, platinum
		Basic intrusions	Iron ore (magnetite)
		Acidic intrusions	China clay
F. Yenisei Ridge	Pre-Cambrian	Acidic intrusion	Gold, mica, thorium
G. Angara Basin	Paleozoic (Permian)	Metamorphic	Coal
H. Baikal-Aldan Piedmont	Paleozoic (Cambrian)	—	—
I. Kansk Basin	Mesozoic (Jurassic)	Sedimentary	Lignite
J. Cheremkhovo (Irkutsk) Basin	Mesozoic (Jurassic)	Metamorphic	Coal, gypsum, salt

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Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
K. Eastern Sayan–Aldan Subsystem	Pre-Cambrian (Lower Paleozoic diastrophism)	Basic (ultrabasic?) intrusion	—
		Acidic intrusion	Arsenic, cerium and rare earths, gold, iron ore (magnetite), mica, tungsten, uranium, zirconium
		Hydrothermal	Lead, molybdenum
		Metamorphic	Andalusite, corundum
	Mesozoic (Jurassic)	Metamorphic	Coal
	Cenozoic (lacustrine)	Sedimentary	Sodium salts (mirabilite)
5. *Khingan-Verkhoyansk System*			
A. Cherskii Horst	Pre-Cambrian (?)	—	—
	Paleozoic (Silurian–Lower Carboniferous). Paleozoic (?) diastrophism	Acidic and basic intrusions	—
B. Yana-Kolyma-Chukchi Uplands (Mesozoic diastrophism)	Mesozoic (largely Triassic)	Acidic intrusion	Fluorspar, gold, lead, tin, tungsten
C. Verkhoyansk-Yudoma Ranges	Permian	—	—
D. Transbaikal Plateau	Undifferentiated Paleozoic to Jurassic (Mesozoic diastrophism)	Acidic intrusion	Beryllium, bismuth, borax (quartz-tourmalines), fluorspar, gold, tin, tungsten
		Hydrothermal	Cadmium, lead, zinc

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Provinces, Formations, and Associated Minerals (Continued)

Province	*Formation*	*Association*	*Known Deposits*
E. Bureya Uplands (Mesozoic Diastrophism)	Pre-Cambrian	Unknown	Antimony, graphite
	Paleozoic	Acidic intrusion	Gold, zirconium (?)
	Mesozoic (Jurassic)	Acidic intrusion	Tin
		Metamorphic	Coal, lignite
F. Sikhote Alin (Mesozoic diastrophism)	Paleozoic	—	—
	Mesozoic	Acidic intrusion†	Bismuth, cadmium, lead, zinc, tin, coal, lignite, iron ore (limonite)
6. *Eastern Asiatic System* (Cenozoic Diastrophism)			
A. Sakhalin Island	Paleozoic	—	—
	Mesozoic	Metamorphic	Coal
	Cenozoic (Upper)	Sedimentary	Petroleum
B. Kamchatka-Koryak Ranges	Paleozoic-Cenozoic	—	—

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* Revised from *Mining World-World Mining*, vol. 3, no. 10, pp. 36–37 (1951), embracing new information from Miranov *et al.*, 1951.

† Not certain whether hydrothermal.

Sources: Primarily, Arkhangel'skii, 1941; Motylev, 1937, map, pp. 96–97; Suslov, 1947, Part II, map 7; Fersman, 1940; Fedorov, 1939; Gorskii *et al.*, 1944; Zakharov, 1938; Kamin, 1938; and sources cited in Chapters III–VIII.

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underlying structures are generally unknown. The associations indicated, though based upon careful examination of the deposit descriptions and correlation with available geological maps, have even greater degrees of probable error.

With these serious reservations, a number of impressions concerning Russia's *ultimate* mineral-producing potentialities may be advanced. First, the wide occurrence of highly diversified geological formations is extremely favorable to new discoveries. Hence, the deficiencies in known resources previously discussed are likely to be transitory in many instances. Placing any limit to what may be found would be foolish. Second, the Kazakhstan Uplands, the Western Sayan Ranges, and the Angara-Yenisei Subsystem appear to be extremely promising, above all for discoveries of ferrous metals (iron ore, chromite, nickel, etc.). At the same time, it is evident that the extreme poverty of the western frontier of European Russia, in terms of known mineral deposits, reflects inadequate exploration as well as adverse natural conditions. Third, the mineral self-sufficiency of the present economic regions is unlikely to be achieved. The closest approaches may be realized in the Urals and Turkestan Economic Regions, both characterized by a wide range of formations. On the other hand, the substantial mineral autarchy of three broad regional groupings — European Russia including the Caucasus; the Urals, Turkestan, and Western Siberia; and Eastern Siberia with the Soviet Far East — might well be achieved. Finally, the transformation of these possibilities into reality would be a task of extraordinary uncertainty, magnitude, and duration. A generation or more of unceasing effort would be little for the task.

Appendix I

MINERAL CONSUMPTION AND UTILIZATION IN THE UNITED STATES

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1. Consumption Trends

Between 1899 and 1923, American requirements for minerals, as measured by the Index of Mineral Consumption, grew steadily; thereafter, continuous growth was not resumed until the decade of the 1940's. In all, between 1899 and 1949, American mineral consumption multiplied almost sixfold. The major determining factor in its development has been the general expansion of the economy, as indicated by the gross national product and comparable measures (see Chap. II, Sec. 3; Grossman and Shimkin, 1952). Specifically, the Index of Mineral Consumption in the United States has had the record given in Table 88.

The courses of consumption for individual minerals have been affected by other factors as well. Since 1899 (temporarily disregarding the war years 1918 and 1944), the proportion of fuels in total American mineral consumption, weighted at 1937 prices, has risen by 30 per cent; while that of other nonmetallics has more than doubled, and that of metals has fallen by a third to a half. The fundamental cause for these shifts has been the increasing use of ferrous and, more recently, nonferrous metallic scrap, including secondary aluminum, antimony, copper, lead, magnesium, nickel, tin, and zinc. This fact is evident from Table 89, the first part of which shows the structure of American mineral consumption, 1899–1949, uncorrected for scrap. The second part of the table, for the same period, has been corrected by including scrap. It shows a fundamental stability in the proportions of major mineral groups, except for a sharp rise in nonmetallics other than fuels and a moderate drop in ferrous metals.

The secular relative decline in ferrous-metals consumption has been caused not only by the increased use of scrap, but also by the

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TABLE 88

Index of Mineral Consumption, United States, 1899–1949
(1935–1939 average = 100)

Year	*Index*	*Year*	*Index*	*Year*	*Index*	*Year*	*Index*	*Year*	*Index*
1899	28								
1900	28	1910	59	1920	89	1930	102	1940	127
1901	33	1911	56	1921	67	1931	84	1941	152
1902	35	1912	63	1922	79	1932	66	1942	157
1903	39	1913	67	1923	104	1933	73	1943	164
1904	38	1914	60	1924	99	1934	78	1944	167
1905	46	1915	65	1925	105	1935	86	1945	163
1906	49	1916	81	1926	112	1936	105	1946	156
1907	53	1917	84	1927	109	1937	111	1947	173
1908	43	1918	87	1928	114	1938	89	1948	182
1909	54	1919	78	1929	118	1939	110	1949	165

Source: For references and methods, see Chap. II, Sec. 3.

slowing of investment in railroads — once steel's greatest customer — and by increased competition from nonferrous metals in specialized construction uses. This decline has had as its consequence a depressing effect upon all steelmaking basics (Group B minerals:

TABLE 89

Structure of American mineral consumption, 1899–1949

	Percentage of Total Consumption (1937 prices)							
	1899	*1909*	*1918*	*1919*	*1929*	*1939*	*1944*	*1949*
Excluding Scrap								
Ferrous metals[a]	30.0	27.1	25.6	20.4	19.9	17.7	20.6	18.2
Nonferrous metals[b]	18.9	11.3	15.2	9.1	11.2	12.1	15.9	12.6
Fuels[c]	47.2	56.1	54.8	64.9	61.1	63.3	58.6	61.6
Other nonmetallics[d]	3.8	5.5	4.4	5.6	7.8	6.9	4.9	7.6
Corrected for Scrap								
Ferrous metals[a]	33.0	31.0	31.7	26.3	28.5	29.0	31.8	27.4
Nonferrous metals[b]	18.0	11.1	15.4	9.9	13.6	14.3	18.6	17.0
Fuels[c]	45.4	52.5	48.2	58.6	51.4	51.1	45.8	49.5
Other nonmetallics[d]	3.6	5.4	3.7	5.2	6.5	5.6	3.8	6.1

[a] Pig iron, spiegeleisen, ferromanganese, ferrosilicon, and half of nickel.
[b] Aluminum, copper, lead, half of nickel, tin, and zinc.
[c] Coal, lignite, natural gas, and petroleum.
[d] Asbestos, cement, industrial diamonds, gypsum, salt, sulfur, and pyrite.
Sources: *The Mineral Industry*, 1899–1939; *Minerals Yearbooks*, 1940–1947; Manuscript information Bureau of Mines.

pig iron, andalusite, chromite, cobalt, columbium, dolomite, fire clay, magnesite, manganese, molybdenum, tungsten, and vanadium); in part, on cerium and rare earths, coal, fluorspar, and nickel. The relative declines of pig iron, manganese, and coking coal have been particularly steady; the relative consumptions of chromite, fire clay, magnesite, molybdenum, tungsten, and vanadium appear to have passed their peaks. Andalusite, cobalt, columbium (niobium), and dolomite alone promise rapid continued gains, relative to the total Index of Mineral Consumption, primarily because of their greatly intensified use in steelmaking. The continuing growths of cerium and rare earths, nickel, and fluorspar derive in large part from the other uses of these minerals. (For details, see Table 90; on the methods of extrapolation, see Chap. II.)

The considerable group of nonferrous metals exhibits diverse actual and foreseeable consumption trends, relative to the Index. Lead and tin have been declining steadily since 1909. Rising prices and increasing scarcity have promoted competition from titanium pigments for the first, and extraordinary economies in plating for the second. Antimony, arsenic, mercury, and zinc seemingly passed their relative consumption peaks in the mid-1930's. All other nonferrous metals appear to be still rising in importance, at moderate to very rapid rates. Copper, almost indispensable in the electric-power industry, is remarkable in being an "old" metal showing no signs of technological "maturity." Other nonferrous metals which may be expected to maintain moderate relative growth are aluminum, cadmium, and nickel. Ilmenite, the source of titanium, important as a pigment and very promising as a metal; magnesium, primarily significant in aircraft construction; and zirconium, with wide uses in electronics, comprise some of the "new," still developing metals. Bismuth marks an interesting special case. The decline of its early medicinal importance led to a sharp fall in its relative consumption between 1909 and 1926; thereafter, however, increasing industrial uses have much more than offset this factor, leading to a considerable secondary rise or "rejuvenation."

Although American fuel consumption, in terms of both dollar value and heat value, has grown more rapidly than the Index of total mineral consumption, coal has been dropping steadily in relative importance since 1909. By 1947, American coal consumption per unit of the Index was less than half the 1909 figure. As a result, the physi-

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TABLE 99

Mineral consumption trends in the United States, normalized at an index of 100 (Hypothetical Standard)

Mineral	*Unit*	*Consumption*					
		1909	*1928*	*1937*	*1944*	*1947*	*1960*[b]
Group A[a]							
Aluminum, primary	10^3 short tons	17.0	87.5	150[c]	455	310	450
Antimony, primary	10^3 short tons	13.5	11.5	16.5	14.5	11.5	8.5[d]
Arsenic	10^3 short tons	7.8	17.5	31.0	26.5	18.0	12.0[d]
Asbestos	10^3 short tons	78.0	230	285	235	355	395[d]
Asphalt	10^3 short tons	?	3800	4750	4100	5200	5600[d]
Barite	10^3 short tons	92.5	255	345	365	490	600
Bauxite (dried equivalent)	10^3 short tons	220	585	735	2650	1690	2200
Beryl	10^3 short tons	—	—	(0.27)	2.7	1.00	1.70[d]
Bismuth	short tons	155	30.0	180	375	(425)	700
Borates	10^3 short tons	(30)	88.5	185	150	245	300[d]
Bromine	10^3 short tons	0.9	0.8	12.0	31.0	18.5[e]	28.0[d]
Cadmium	10^3 short tons	—	0.44	2.55	2.70	2.30	3.00
Cerium (see Monazite)							
China clay (kaolin)	10^3 short tons	(280)	650	700[e]	560	875	1000[d]
Coal (bituminous equivalent)	10^3 short tons	750	550	430	400	350	235
Copper, primary	10^3 short tons	595	700	625[c]	920	755	905
Corundum	10^3 short tons	(4.0)	4.75	1.85[c]	3.90	2.05[e]	0.21
Diamonds, industrial	10^3 carats	—	37.0	1700	7700	2500[e]	3300[d]
Emery	10^3 short tons	(4.0)	4.65	4.80	4.25	5.25	6.05
Fluorspar	10^3 short tons	(100)	180	195	250	210[e]	235
Graphite	10^3 short tons	40.8	21.5[f]	21.0[g]	20.0[h]	25.5[e]	32.0[d]
Gypsum	10^3 short tons	4850	5750	3550[c]	2550	4900	4500
Ilmenite (titanium ore)	10^3 short tons	—	4.3	140	220	280	455
Lead, primary	10^3 short tons	680	640	405	475	390	210
Magnesium, metallic, primary	10^3 short tons	—	0.15	2.05	81.0	4.10	8.85
Mercury	10^3 flasks[i]	25.5	30.0	31.5	26.5	21.0	13.0

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TABLE 90 (Continued)

Mineral	*Unit*	*Consumption*					
		1909	*1928*	*1937*	*1944*	*1947*	*1950*[a]
Mica: muscovite and phlogopite—							
sheet and splittings	10^3 short tons	2.25	2.70	2.70	4.65	3.80[e]	4.70
scrap and ground	10^3 short tons	4.5	6.35	22.5	32.0	30.5	31.5
vermiculite	10^3 short tons	—	—	(22.0)	33.0	77.0	110
Monazite sands							
(Cerium, rare earths, thorium)	short tons	455	310	3100	1200	1650	2450
Natural gas	10^9 ft^3	815	1170	2150	2250	2600	2800
Nickel, primary	10^3 short tons	8.6	20.0	45.0	77.0	46.5	72.0
Petroleum, crude	10^6 bbl.	815	730	1050	1000	1150	1250[d]
Phosphate rock	10^3 short tons	2250	2450	2950	3450	4900	6150
Piezoelectric quartz crystals	short tons	—	—	—	570	40[e]	100
Platinum metals	10^3 troy oz.	200	150	155[e]	275	270[e]	355
Potash (K_2O equivalent)	10^3 short tons	280	260	385	460	395	800
Salt (sodium chloride)	10^3 short tons	7350	6850	8800	9500	9500[e]	11,000
Sodium salts (natural Na_2SO_4, Na_2CO_3)	10^3 short tons	?	(380)	380	210	250	320
Strontium (Sr minerals, etc.)	10^3 short tons	?	2400	2850[e]	5400	5000[e]	7300
Sulfur and pyrite[d]	10^3 short tons	1350	1750	2250[e]	2300	2500[e]	2900
Talc	10^3 short tons	235	200[f]	225	240	305	375
Tantalum (ore)	short tons	—	1.1	1.6[a]	235	130	200
Thorium (see Monazite)							
Tin, primary	10^3 short tons	80.5	73.5[f]	68.0	40.5	39.0	16.0
Titanium (see Ilmenite)							
Zinc, primary	10^3 short tons	460	495[f]	310	315	495[e]	445
Zircon	10^3 short tons	—	1.1	8.0	8.9	17.0	25.5
Pig iron (excluding ferroalloys)	10^3 short tons	48.5	39.0[f]	34.5	36.5	31.5[e]	25.0
Group B[i]							
Andalusite	short tons	—	—	970	3200	2150	4200
	short tons	—	—	*3350*	*11,700*	7400	*10,500*
Chromite	10^3 short tons	15.5	56.5	165	140	155[e]	160
	10^3 short tons	*75.5*	*220*	*570*	*510*	490	*350*

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TABLE 90 (Continued)

Mineral	*Unit*	*Consumption*					
		1909	*1926*	*1937*	*1944*	*1947*	*1960*[b]
Cobalt	short tons	1.7	84.0	250	445	410[e]	520[d]
	short tons	*8.3*	*330*	*860*	*1620*	*1300*	*1300*
Columbium ore	short tons	—	—	120	300	240	440
	short tons	—	—	*415*	*1095*	*755*	*1100*
Dolomite	10^3 short tons	—	300	545[g]	755	800[e]	1000[d]
	10^3 short tons	—	*1170*	*1880*	*2760*	*2520*	*2500*
Fire clay	10^3 short tons	490	650	710	1020	1530	1200[d]
	10^3 short tons	*2350*	*2350*	*2450*	*3700*	*5100*	*3000*
Magnesite	10^3 short tons	43.0	52.0	72.0[g]	92.0	68.5[e]	60.0[d]
	10^3 short tons	*210*	*200*	*250*	*335*	*215*	*150*
Manganese (content)	10^3 short tons	190	145	185	130	175[e]	150[d]
	10^3 short tons	*[illegible]10*	*565*	*640*	*550*	*550*	*375*
Molybdenum	short tons	—	160	1680[g]	2570	1750	2250[d]
	short tons	—	*625*	*5800*	*9400*	*5500*	*5500*
Tungsten (60% WO_3 equiv.)	short tons	560	925	1650	3300	1400[e]	1250[d]
	short tons	*2700*	*3600*	*5700*	*11,000*	*4400*	*3100*
Vanadium	short tons	?	250[f]	470	440	275	225[d]
	short tons	?	*975*	*1620*	*1600*	*865*	*560*

[a] All minerals except the ferrous group, normalized to a mineral consumption index of 100.

[b] Linear extrapolation of the 1926–1929 and 1946–1947 averages, except as adjusted; cf. note d.

[c] Affected by depression; to fit the secular trends, raise as follows: for aluminum and bauxite, by 25 per cent; china clay, 10 per cent; copper, 30 per cent; corundum, 60 per cent; gypsum, 35 per cent; platinum, 40 per cent; strontium, 30 per cent; tantalum, 650 per cent.

[d] Adjusted to extrapolation.

[e] Average of 1946, 1947.

[f] Average of 1926, 1929.

[g] Average of 1934, 1937.

[h] Average of 1940, 1944.

[i] Weight of flask, 76 lb.

[j] Pyrite at 45 per cent of physical weight (equal to average sulfur content).

[k] Average of 1937, 1940.

[l] Normalized at a consumption of 10 million short tons of pig iron; consumption at the rate of an index of 100 shown italicized.

Sources: The Mineral Industry, XVIII (1910); *Mineral Resources of The U. S.*, 1926–1929; *Minerals Yearbooks*, 1934–1947.

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000 cal weight of all American mineral consumption (excluding stone, sand, and gravel) per unit of the Index has been cut almost in half over this period. Because of this fact, and because petroleum and natural gas, which have increased in importance, move primarily by pipeline rather than rail, the need for rail-freight transportation in the United States has grown very slowly, with the depressing effects on ferrous-metals consumption previously mentioned.

Most nonmetallic minerals are characterized by steady increases relative to the Index of Mineral Consumption. This has been particularly true for industrial diamonds, essential for precision machinery and instrumentation; piezoelectric quartz crystals, vital in electronics; the excellent insulator, vermiculite mica; and the refractory, dolomite. Substantial growth has also been exhibited by a number of building materials (asbestos, asphalt) and fertilizer-making minerals (phosphate rock, potassium, and sulfur). Other industries significantly affecting the relative rise of nonmetallic minerals have been the petroleum, for barite; the detergent, for borates; the paper, for china clay; aluminum manufacture, glass, and refrigeration, for fluorspar; and the electrical and construction industries, for mica. A number of nonmetallic minerals have been "rejuvenated," after earlier declines, through the discovery of new uses. These include bromine, graphite, salt, and talc. Finally, only a few — corundum, gypsum, fire clay, and magnesite — appear to have passed their peaks of relative consumption.

Thus far, the entire discussion of consumption has been devoted to secular trends, as actually studied for the period 1909–1947, and as extrapolated to 1960 (see Table 90). But it must be emphasized that at least two factors have introduced important shorter-run deviations from these apparent trends.

The first of these was the period of excessively low investment during the 1930's, which is partly illustrated by the 1937 data, but most clearly between 1932 and 1936. During these years, petroleum consumption deviated upward from its secular trend relative to the Index by 10 to 15 per cent, possibly in reflection of the greater importance of services. Similarly, tin consumption deviated upward by 5 per cent, marking the relatively greater significance of the food industries (tin plate). The numerous relative declines included the following: 10–25 per cent for china clay, zinc, asphalt, and copper; 30–45 per cent for asbestos, pig iron, and platinum; and 50–80 per cent for aluminum (bauxite), corundum, gypsum, and vanadium. 000 Such changes are understandable. They include materials for the construction, electrical, machine-building, and transportation-equipment industries, all of which stagnated during the 1930's. Comparisons with an economy like the Soviet, which has been constantly marked by high investment, must therefore correct for this specific episode in American economic history.

The other factor introducing major variations from secular trends has been the transition to a wartime economy. Reference to Table 89, illustrating the structure of American mineral consumption between 1899 and 1949, shows that both 1918 and 1944 were marked by significant increases in the proportions of metals consumption, and by decreases in fuels, and especially in other nonmetallic minerals. In more detail, and correcting for special circumstances such as the loss of Malayan tin and the early wasteful use of piezoelectric quartz crystals, the following shifts appear to be functionally connected with present-day war requirements, and the concomitant structural shifts from a consumers'-goods to a militarized economy.

Increases (including, for Group B minerals, the effects of changes in pig-iron consumption):

Over 150 per cent — piezoelectric quartz crystals, industrial diamonds, beryl, and tantalum;
105–95 per cent — andalusite, aluminum (bauxite), and tungsten;
75–60 per cent — manganese, molybdenum, corundum, and bromine;
40–35 per cent — niobium (columbium) and cobalt;
15–10 per cent — pig iron, copper, strontium, arsenic, and coal.

Decreases:

10–15 per cent — petroleum, natural gas, and barite;
20–30 per cent — asphalt, emery, potash, tin, asbestos, and borates;
35–45 per cent — sodium salts and gypsum.

2. *Detailed Uses and Technological Characteristics of Individual Minerals*[*]

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[*] With Edith M. Shimkin.

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The present-day economy of the United States uses at least one hundred groups of minerals. Their major applications may be grouped into nine large and many smaller categories (e.g., papermaking).

The *chemical industries* require probably the greatest range of minerals. A number are the raw materials for terminal products, e.g., natural gas for synthetic rubber, fluorspar for the refrigerant Freon. Many more, such as cobalt, platinum, and zirconium, are used as intermediate products or catalysts. Ore dressing, smelting, and refining, closely allied to the chemical industries, utilize many of the same and other minerals: aluminum, barite, coal, etc. The manufacture of almost all *machinery and transportation equipment* requires iron, manganese, copper, lead, zinc, and aluminum. Special high-speed, high-temperature, heavy-duty equipment demands many alloys, e.g., chromium, molybdenum, nickel, tungsten, and vanadium. To make precision machinery, abrasives are needed; these include corundum, emery, and diamonds, as well as artificial abrasives from bauxite, tungsten, and tantalum. *Fluxes, solders, and babbitts* for joints and moving parts are made from antimony, bismuth, cadmium, lead, tin, and other elements. *The electrical and electronics* industries depend upon copper, aluminum, tungsten, molybdenum, barium, cerium, graphite, mercury, piezoelectric quartz, platinum, and thorium. The *construction and road-building* industries require large-scale use of nonmetallic minerals, especially china clay, gypsum, magnesite, asphalt, asbestos, vermiculite mica, and talc. Iron (including many mild-steel alloys), copper, lead, zinc, and aluminum go into frames, roofing, plumbing, and wiring. Also, andalusite, bauxite, beryllium, china clay, chromite, graphite, magnesite, talc, thorium, and zirconium are used for furnace linings, and *other refractory* purposes. *Paints, enamels and dyes derive* from barite, china clay, coal, lead, titanium, and zinc; special types (e.g., marine antifouling paints) use antimony, chromite, cobalt, and mercury. Basic materials for *glass and ceramics* include silica and clays, barite, fluorspar, salt, and sodium sulfate, and occasionally arsenic, gold, cobalt, etc. The major *fuels* include coal and lignite, petroleum, and natural gas. The effectiveness of light petroleum fractions is enhanced, however, by *blending agents*, particularly bromine and lead compounds. *Lubricants* come largely from petroleum and natural gas, but fortified greases also require sodium, potassium, and other elements.

Graphite is the outstanding inorganic lubricant. The major *fertilizers* 000 are nitrates, gypsum, phosphates, and potash, but smaller quantities of other minerals, such as manganese, are also vital. The production of fertilizers necessitates large-scale use of sulfuric acid, salt, and other reagents. Among *foodstuffs, pharmaceuticals, and toxic agents*, salt and iodine are outstanding, but arsenic, bismuth, bromine, mercury, potash, radium, and strontium are also significant.

In all, most minerals have multiple uses. Some, such as iron, salt, sulfur, and limestone, are essential to nearly all economic activities. Only a few, such as piezoelectric quartz crystals and diamonds, have but one major industrial application. Consequently, appreciable substitution is normally possible in the uses of many minerals, with the determining factors lower costs, better availability, and a margin of quality.

The primary sources utilized in this survey have been the following: U. S. Bureau of Mines' *Minerals Yearbooks* (1938–1947), Taggart (1945), Bateman (1942), DeMille (1947), Dolbear and Bowles (1937), Pierce (1947), and U. S. Bureau of Mines (1937).

Aluminum (see *Bauxite*). Uses: pure and alloyed with copper (duralumin) and silicon (siluminum), wherever lightness and rigidity are needed, especially in aircraft and other transportation; pure aluminum, for high-tension transmission lines; secondary aluminum, as deoxidizer in steel manufacture; also for corrosion-resistant purposes in containers for volatile chemicals, construction, cooking utensils, etc. Substitutes: in part, magnesium, ultimately, metallic titanium. Scrap aluminum, almost all recovered in alloy form, is not suitable for aircraft construction and other highly responsible purposes, but has otherwise gained increasing importance, constituting 37 per cent of the total U. S. aluminum supply in 1947, in reflection of improved remelting processes.

Andalusite and related aluminum silicates. Theoretical composition: $Al_2O_3 \cdot SiO_2$; kyanite and sillimanite have the same composition but different crystal forms. Uses: heavy-duty, stable, and long-lived refractory in metallurgy; additive to increase the strength, viscosity, and stability of glass; glass-plant refractories and refractory cements; spark-plug cores and laboratory ware. Melting point, 3290°F. Substitutes: synthetic mullite, from electrically fused diaspore ($Al_2O_3 \cdot H_2O$) and, in part, magnesite. Ore treatment: concentration to 84–94 per cent; 80 per cent recovery; water requirements, 7 tons/

ton of ore milled; power requirements, 26 kwhr/ton of ore milled.

Antimony. Most important ore: stibnite (Sb_2S_3). Utilization (percentage of total in 1947): antimonial lead and battery metal (4–12 per cent Sb), 38 per cent; bearing metal and bearings, 13 per cent; frits and ceramic enamels, 10.6 per cent; paints and lacquers, 8 per cent; type metal, 7 per cent. In war, flameproofed textiles consume nearly 40 per cent of the total. Substitutes: barium, calcium, and lead alloys in part. Recoverable from scrap: in 1947, secondary output exceeded primary by 50 per cent. Ore treatment for stibnite, hand sorting and liquation, with recovery under 70 per cent; from antimonial lead, by-product.

Arsenic. Most important ore: arsenopyrite ($FeAsS$). Uses: insecticides and weed killers (62–80 per cent U. S. consumption, 1937–1944); metallurgy, especially for arsenical copper; glass manufacture; dyestuffs; wood preservatives; medicine; military toxic agents. Substitutes (glass manufacture): antimony, cerium, sodium sulfate. Ore treatment: normally a by-product of lead and copper smelters; concentrate, 99 per cent + As_2O_3.

Asbestos. Most important type, chrysotile ($3MgO \cdot 2SiO_2 \cdot 2H_2O$) from serpentine rocks. Uses: very diversified in manufacturing, transportation, electrical industry, and construction wherever heat insulation or fire or electrical resistance are needed. Long-fiber asbestos is used for spinning pliable textiles, e.g., for brake linings; nonspinning fiber is a substitute wherever rigid molded insulation can be used. Substitutes: various, for heat and cold insulation; none, for other properties. Ore treatment (Canada, 1929); complex process of rock crushing, drying, and pneumatic separation. Recovery: 5 per cent of rock mineral, 7.7 per cent of rock milled; product includes 1.5 per cent of fibers 0.375 in. or longer, and 90 per cent nonspinning grades.

Barite and witherite. Composition: $BaSO_4$ and $BaCO_3$, respectively, the latter being rare. Utilization (percentage of total in 1947): oil-well drilling mud, 56 per cent; for paints, especially as lithopone (with minimum of 95–97 per cent $BaSO_4$, 1 per cent Fe_2O_3 maximum), 19 per cent; chemicals used in explosives, casehardening steels, purification of beet sugar, manufacture of hydrogen peroxide, 20 per cent; glass, 2 per cent; other uses are as a rubber filler and, as metallic barium, a vacuum-tube "getter." Substitutes: titanium pig-

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ments for lithopone. Ore treatment: sorting, crushing, bleaching with sulfuric acid, and fine grinding.

Bauxite (*aluminum*). Bauxite: variable sedimentary mineral typically containing 55–65 per cent Al_2O_3, 2–5 per cent SiO_2, 1–25 per cent Fe_2O_3, etc. Utilization (percentage of total in 1947): production of aluminum, at approximately 4 tons of bauxite to 1 ton of aluminum, 83 per cent; abrasives (Al_2O_3), 9 per cent; chemicals, particularly aluminum sulfate (colloid), for catalytic cracking in petroleum, 5.7 per cent; also, aluminous cement.

Bauxite for metallurgical and chemical purposes requires 50 per cent Al_2O_3 minimum; SiO_2, 4.5 per cent, and Fe_2O_3, 6.5 per cent, maximums, except with the limerock sinter process, when 13 per cent, SiO_2 can be tolerated. Substitutes: none satisfactory. Ore treatment: washing, breaking, and drying (1100°F; 2000°F for refractories and abrasives); for aluminum manufacture, alumina prepared by digestion with sulfuric acid (recovery increased from 70 per cent to 85–90 per cent with high-silicon bauxite by sintering "red mud" precipitate with limestone and soda ash), then alumina reduced to metallic aluminum by electrolysis in cryolite. Power requirements: 9 to 10 kwhr/pound of metal.

Beryllium. Ore: beryl, $3BeO \cdot Al_2O_3 \cdot 6SiO_2$. Uses: Beryllium-steel and copper alloys (0.1–3.5 per cent Be) wherever very high resilience, strength, high electrical conductivity, and wear resistance are needed, especially in instruments, valves, etc.; electronics; very-high-temperature refractories (melting point, BeO, 4352°F). Substitutes: not known. Ore treatment: difficult, details not available.

Bismuth. Ore: native bismuth, bismuthinite (Bi_2S_3), and bismite (Bi_2O_3). Utilization (percentage of total in 1947): pharmaceuticals, 52 per cent, low-melting-point alloys (43–55 per cent Bi) for patterns, coatings, and fusible plugs (29 per cent of U. S. consumption, 1944); solders and bearings (14 per cent of U. S. consumption, 1944); added to aluminum, stainless steel, etc., to increase machinability; special uses in radar and atomic research. Substitutes: biologicals for medical applications. Ore treatment: normally, a by-product of lead and tin refining: fusion with caustic soda and soda ash, electrolysis.

Borax. Composition, $Na_2B_4O_7 \cdot 10H_2O$. Uses: enamels, glass, fertilizers, water-softeners, antiseptics, fireproofing, flux for welding, etc.; boron compounds in oils, varnishes, etc.; source of metallic

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boron, used for boron carbide (abrasive), ferroboron (added in about 0.002 per cent to steels to improve mechanical properties). Substitutes: not ascertained. Ore treatment: in general, dissolution in hot water or steam, evaporation, and fractional crystallization.

Bromine. Sources: $MgCl_2$ and $CaCl_2$ brines, sea water. Uses: primarily for ethylene dibromide (antiknock agent for gasoline), 91 per cent of total in 1947; photographic emulsions; numerous chemical, metallurgical, and pharmaceutical applications. Substitutes: not known. Concentration procedures: not available.

Cadmium. Source: by-product of zinc ores (average proportion 1 Cd to 200 Zn). Uses: electroplating of metals for corrosion resistance (59–88 per cent of U. S. consumption, 1941–1944); heavy-duty bearings (9–19 per cent of U. S. consumption, 1941–1944); low-temperature solders; cadmium compounds for pigments, photoelectric cells, etc. Substitutes: zinc, for electroplating; various, for bearing metals; bismuth, for solders. Ore treatment: separation from zinc concentrates by fractional distillation or electrolysis.

Cerium and Rare Earths. Ore: primarily, monazite sands, approximate formula, $(Ce,La)PO_4$. Uses: in arc carbons, searchlights, etc.; for optical glassware; vacuum-tube "getter"; as mix metal (ferrocerium) in ignition devices and to deoxidize cast iron; as alloy for heavy-duty iron castings; cerium acetate, for waterproofing and antimildew compounds. Substitutes: not ascertained. Ore treatment: mechanical and magnetic separation, followed by complex chemical treatment.

China clay (kaolin). Composition, an impure kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot H_2O$) mixed with feldspar, quartz, mica, and other minerals. Uses: paper filler and coatings (59 per cent of U. S. consumption, 1944); refractories, molding sands, and ceramics (especially electrical insulators); rubber; paints; cement, high-grade tiles, etc. Substitutes: fire clay and other clays (for lighter-duty purposes); andalusite, diaspore (for heavy-duty purposes). Ore treatment: dry or wet removal of sand and grit; froth flotation to separate finest grades of clay, and recover mica. Recovery (one U. S. mill), 88 per cent.

Chromite. Composition, $FeO \cdot nCr_2O_3$ with many admixtures, found in ultrabasic igneous rocks. Uses: as ferrochrome, to prepare low-chromium (4–0.5 per cent Cr), intermediate-chromium (3–12 per cent Cr), and high-chromium (12–30 per cent Cr) steels for machinery and ordnance, including exhaust valves, turbine blades, and other parts subject to high pressures, high temperatures, and corrosion; to prepare stellites (20–35 per cent Cr, plus Co, W, Mo) for high-speed tools; for electroplating. Metallurgical chromite should have a Cr:Fe ratio of 3:1. The second major use is for strong, high-temperature refractories (melting point, 3200°–3722°F); chromite for this purpose may be low in Cr_2O_3 if Al_2O_3 content is high. The third major use is in chemical industries, for tanning, producing pigments, pickling nonferrous metals, and as a catalyst for producing synthetic rubber and gasoline. Chemical chromite requires a minimum of 45 per cent Cr_2O_3. In 1947, 46 per cent of the chromite consumed was for ferrochrome; 37 per cent, for refractories; and 17 per cent, as a chemical. Substitutes: diaspore, for refractories. Ore treatment: in better deposits, hand sorting only. Lower-grade ores (3–20 per cent Cr_2O_3 feed) require mechanical and magnetic separation, and flotation to produce a 40 per cent Cr_2O_3 concentrate with 85 per cent recovery. 000

Coal and lignite. Classification, in U. S. practice: generally, according to ascending degree of metamorphism as lignite, subbituminous, bituminous (high-to-low volatile), and anthracite. Lignites have relatively very low heat value, and are greatly subject to weathering, so their consumption in the U. S. is negligible. Bituminous coals have maximum heat value and also a large gas output valuable for coal-tar extraction and coking. Anthracite coals are hard and smokeless, thus best adapted for space heating. Uses: as fuel, and raw material for pig-iron and steel production, and for chemical by-products (gas, tar, ammonia, etc.). Utilization trends in the United States are summarized in Table 91. Substitutes: for fuel, petroleum, natural gas, peat, and firewood; for other uses (in part), petroleum and natural gas. Ore treatment: highly variable. Some trends in the United States are illustrative (Table 92).

Cobalt. Ores: primarily cobaltite (CoAsS) and related complex arsenides and sulfides, in magnetite, copper, or nickel deposits. Utilization (percentage of 1947 total): magnetic steels, 24 per cent; ground-coat frit and pigments, 20 per cent; cobalt salts, and driers, for pigments and as catalysts for the oxidation of ammonia, production of synthetic gasoline by the Fischer-Tropsch process, etc., 19 per cent; stellites (up to 60 per cent Co), for heat-resistant, high-speed tools, 16 per cent; for surgical and other corrosion-resistant, low-speed steels, 9 per cent; for high-speed tool steels, 5 per cent.

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TABLE 91

Trends in use of bituminous coal in the United States (percentages of total consumption)

Use	*1929*	*1937*	*1943*
Fuel			
Class I Railroads	21.0	19.8	20.8
Electrical power	8.4	9.6	12.4
Retail delivery	?	17.9	19.6
Export and bunker, colliery	4.7	4.3	est. 3.6
Other			
Coke, by-product	14.3	15.4	14.4
beehive	1.9	1.1	1.9
Steel and rolling mills	?	2.9	1.8
Cement mills	?	1.2	0.8
Coal-gas retorts	?	0.3	0.3
Other industrial	?	27.5	21.6

TABLE 92

Production methods and efficiency of use of coal in the United States

	1923	*1936*	*1943*
Bituminous coal			
Underground output cut by machine (per cent)	68.3	84.8	90.3
Underground output loaded by machine (per cent)	0.3	16.3	48.9
Mined by stripping (per cent)	2.1	6.4	13.5
Cleaned by wet or pneumatic processes (per cent)	3.6	13.9	24.7
Output per man per day (net tons)	4.47	4.62	5.4
Output per man per year (net tons)	801	920	1419
Efficiency of use			
Pounds of coal per kilowatt hour	3.2*	1.44	1.3
Pounds of coking coal per ton of pig iron	3194*	(2900)	2620
Pounds of coal per 1000 gross ton-miles of railroad freight	170*	119	114
Anthracite coal			
Underground output cut by machine (per cent)		3.9	2.7
Underground output loaded by machine		19.9	24.3
Mined by stripping (per cent)		11.4	14.6
Output per man per day (net tons)		2.79	2.78
Output per man per year (net tons)		535	751

* For 1919-20.

Substitutes: in part, for high-speed steels, tungsten and molybdenum. 000 Ore treatment: (from arsenical cobalt ores) roasting, smelting to produce high Ag-Co-Ni-Fe speiss, dissolution in acid, fractional precipitation; reduction of cobalt oxide to metal; (from magnetite: feed, 0.086 per cent Co), magnetic separation, flotation to produce 1.39 per cent Co concentrate (64.7 per cent recovery), concentrate roasted and chemically treated, total recovery about 50 per cent.

Copper. Ores: very numerous, but especially native copper and copper sulfides — chalcocite (Cu_2S), chalcopyrite ($CuFeS_2$), etc.; also copper carbonates — malachite ($2CuO \cdot CO_2 \cdot H_2O$), etc. Uses: as pure metal, alloy (bronze, brass), or coating in electrical equipment, ammunition, wire and wire cloth, piping, heat-transfer equipment, etc. Substitutes: in part, aluminum (for electrical and heat-transfer equipment), lead (for piping). Refined secondary copper may be used interchangeably with virgin copper, and constituted 42 per cent of the total U. S. copper supply in 1947. Ore treatment: for high-grade ores, with 6 per cent Cu or better, direct smelting; for others, concentration by crushing, grinding, and flotation. In concentration, recoveries range from 90 to 97 per cent in good feeds and 85–90 per cent for low-grade sulfide copper; power requirements range from 1.0 to 2.2 kwhr ton of ore treated; water requirements, 2.5 to 4.0 tons/ton of ore treated, with 50 per cent recovery possible. Smelting recoveries range from 85 per cent to over 99 per cent.

Corundum and emery. Composition: corundum, Al_2O_3; emery, intimate mixture of corundum and magnetite. Uses: abrasives for precision optical equipment and machinery. (Corundum has a hardness of 9 mohs, exceeded only by diamond; its melting point is 3722°F.) Substitutes: carborundum (from electrically fused bauxite) and other artificial abrasives have displaced corundum to a large degree. Metallic abrasives are competitive with emery. Ore treatment: crushing, magnetic separation, and sizing on vibrating screens according to grade.

Diamonds. Ores: Pre-Cambrian basic igneous rock (kimberlite); secondarily, gravel placers. Uses: hardest known abrasives (10 mohs), indispensable in producing precision tools, truing wheels, wire-drawing dies, in cutting and drilling glass, etc. Diamond dust is used in making abrasive wheels for machining extremely hard alloys. Substitutes: in part, tungsten carbide and tantalum carbide.

000 Ore treatment: repeated crushing, screening, washing, and grease-table separation.

Fluorspar. Composition: CaF_2; often found in very pure deposits, sometimes with an admixture of barite. Uses: as a flux, in basic open-hearth and basic electric steel furnaces, 5 to 8 lb and 13.3 lb per long ton of steel, respectively. The next largest use is for manufacturing hydrofluoric acid, essential in making synthetic cryolite (in turn, essential to aluminum making), and refrigerating media (especially Freon); in the electrolytic refining, pickling, and electroplating of metals; for carbon electrodes; for making aviation gasoline, etc.

In addition, fluorspar is employed in making glass and enamels. In 1947, steel utilized 58 per cent of fluorspar consumption; hydrofluoric acid, 26 per cent; and glass and enamels, 12 per cent. Minimum specifications for metallurgical fluorspar ore: 85 per cent CaF_2, 5 per cent SiO_2, and 0.3 per cent S maximum; for acid-grade fluorspar, 98 per cent CaF_2, 1 per cent SiO_2, 0.02 per cent S, 1 per cent H_2O, maximum; for ceramic-grade fluorspar, 95 per cent CaF_2, 2.5 per cent SiO_2. Substitutes: none. Ore treatment: hand-picking, washing, and gravity concentration or flotation. Average recovery; about 72 per cent, varying according to grade of feed.

Gold. Ores, extremely variable. Uses: primarily a monetary medium; for ornamentation; also in chemical industries, precision instruments, dentistry, glassmaking. Substitutes: none, as a basic monetary standard. Ore treatment: highly variable, with recoveries ranging from 60 to 95 per cent (80 per cent average as a by-product from copper ores).

Graphite. Composition: highly metamorphosed carbon usually associated with schists; graded according to size of crystal, from lump to amorphous, and by purity (carbon content). Utilization (percentage of 1947 total): foundry facings and crucibles (infusible), 56 per cent; electrodes, dynamo brushes, and dry batteries, 17 per cent; lubricants, 14 per cent; lead pencils, 7 per cent; moderator in atomic piles (extremely high purity needed). Substitutes: synthetic graphite (electrically fused carbon), primarily for electrodes. Ore treatment: crushing and froth flotation. High recoveries (87 per cent) require delicate separation. For very high purity, graphite requires chemical purification.

Gypsum. Composition: $CaSO_4 \cdot 2H_2O$. Utilization (percentage of total in 1947): primarily in construction (wallboards, plasters, etc.), 63 per cent; as a Portland-cement retarder (3 per cent added), 22 per cent; as a fertilizer, 9 per cent; for making fine casts and molds; for nickel smelting. Substitutes: none in appreciable quantities. Ore treatment (only high-grade ores economically usable): screening and crushing, calcining in kilns. 000

Iodine. Sources: largely oil-well wastes. Uses: disinfectant; in photographic emulsions, in organic syntheses, and in human and animal food. Substitutes: various, for disinfectants. Refining methods: not available.

Iron ore. The main types are hematite, magnetite, titaniferous magnetite, and limonite (see Table 93). Uses: essentially for metallurgy (steel, wrought and cast irons, ferroalloys); secondarily, for cement and paint manufacture, and as a reducing agent. Substitutes: scrap iron and steel, in about a 1:1 ratio with primary pig iron. Ore treatment: in general, limited to screening and washing (average recovery at Mesabi, about 65 per cent); excessively fine grades of iron ore are usually sintered with mill cinders to form larger agglomerates. (In 1944, 20 per cent of the iron ore produced in the United States had been beneficiated; 12 per cent, sintered. Average recovery in sintering, 85 per cent.)

TABLE 93

Composition of iron ores (United States)

Ore	*Theoretical Formula*	Composition (*per cent*)					
		Fe	*P*	*S*	SiO_2	Al_2O_3	TiO_2
Hematite	Fe_2O_3	42–61	0.02–0.50	0–0.1	0–40	0–6	—
Magnetite	Fe_3O_4	40–67	0.02–1.2	0.08–0.42	1–20	0.7–4.5	—
Titaniferous magnetite	$Fe_3O_4 \cdot TiO_2$	34–63	0–0.06	—	0.8–18	2.5–10	12–16
Limonite	$2Fe_2O_3 \cdot 3H_2O$	43–55	0.09–0.48	0.01–0.09	11–19	2–6	—

Lead. Ore: primarily galena (PbS), usually closely associated with sphalerite (ZnS). Utilization (percentages of total in 1947): pigments (red lead and litharge, white lead), 33 per cent; storage batteries, 16 per cent; cable coverings, 14 per cent; tetraethyl lead for high-octane gasoline, 12 per cent; also solder, pipe, ammunition, bearing metals, brass and bronze, etc. Substitutes: scrap lead (44

000 per cent of all U. S. lead consumption, including antimonial lead, in 1947); zinc, titanium, and barium pigments. Ore treatment: crushing, gravity concentration, grinding, and flotation (to yield 75–80 per cent Pb concentrate). Recoveries, usually 95–98 per cent; rarely, under 90 per cent. Power consumption: about 15 kw-hr/ton of ore. Smelter recoveries range from 80–95 per cent of the concentrate.

Magnesite, magnesium salts and metallic magnesium. Magnesite: composition, $MgCO_3$. Uses: primarily for open-hearth steel-furnace linings and other high-temperature refractory purposes (melting point 3425° to 5072°F); for marine cement flooring; to produce caustic-calcined magnesia for fertilizers, epsom salts, and rubber; and as a source of metallic magnesium. Substitutes: as a refractory, chromite and dolomite (for lighter duty); for other purposes, magnesium salts and sea water. Ore treatment: selective mining, hand sorting and sizing, roasting in kilns.

Magnesium salts: source, primarily sedimentary bodies of carnallite ($KCl \cdot MgCl_2 \cdot 6H_2O$). Uses: source of caustic-calcined magnesia and metallic magnesium. Substitutes: magnesite, sea water. Ore dressing: not available.

Metallic magnesium: sources, magnesite, magnesium salts. Uses: primarily in alloys for aircraft construction and in light, rigid castings; also in explosives, as a deoxidizer and catalyst in chemical processes. Substitute: aluminum. Secondary magnesium consumption exceeded primary by 34 per cent in 1947. Preparation: generally, electrolysis of fused magnesium salts in a bath of mixed Mg, Ba, and Na fluorides.

Manganese. Ores: pyrolusite (MnO_2) and psilomelane (approximately, H_4MnO_5). Uses: primarily, in steel production (in 1944, 13.3 lb of Mn were utilized per short ton of steel produced, of which 11.7 lb were as ferromanganese, 0.6 lb as spiegeleisen, 0.9 lb as silicomanganese, and 0.1 lb directly). Also important is its use in batteries, which require manganese with minimum Fe, As, Cu, Ni, and Co contents. Chemical uses include photography, fertilizers, and paints. However, all nonmetallurgical uses together took less than 5 per cent of U. S. manganese consumption in 1947. Substitutes: none in metallurgy. Ore treatment: generally, washing and gravity concentration. Recoveries, 80–86 per cent.

Mercury. Ore: cinnabar (HgS), almost exclusively. Utilization (percentages of total in 1947): electrical, including vapor lamps and military dry-cell batteries, 19 per cent; catalysts, 17 per cent; electrical and heat-control switches, instruments, 16 per cent; agriculture, 17 per cent; pharmacy and dentistry, 11 per cent; antifouling marine paints, 2 per cent; fulminate for munitions and blasting caps, 1.5 per cent. Substitutes: lead azide, for about one-third of consumption; zirconium. Ore treatment: coarse crushing and heating to 500°–600°C. Recovery: 85–95 per cent with modern methods, and about 0.25 per cent Hg feed. 000

Mica: muscovite, phlogopite, and vermiculite. Compositions: muscovite, $H_2KAl_3(SiO_4)_3$; phlogopite, $(H,K,MgF) \cdot Mg_3Al(SiO_4)_3$; vermiculite, altered (hydrated) mica of varying compositions.

Muscovite and phlogopite: uses, for block and sheet mica, as essential insulators in all types of electrical and electronic equipment. Special uses, such as radio condensers, require high-grade mica; flexible phlogopite is essential for aviation spark plugs. Substitutes: in part, built-up scrap and ground mica, the latter for molded insulation; block or die-pressed powdered talc. Ground mica: primarily for roofing (62 per cent in 1947) and paint (13 per cent in 1947). Ore treatment: hand sorting, cleaning, splitting, and trimming of the sheets; for ground mica, dry or wet milling and screening, also by-product from china-clay treatment.

Vermiculite: uses, mainly thermal and acoustic insulation (vermiculite expands on heating). Substitutes: synthetic silicates, asbestos. Ore treatment: crushing, hand picking, screening, and drying. Recovery: 20 to 50 per cent. Exfoliation by heating to 2000°F; pneumatic cleaning. Recovery, about 90 per cent.

Molybdenum. Ore: primarily molybdenite (MoS_2). Uses: about 70 per cent in steel, in alloys (0.15–0.4 per cent) to intensify the effects of other alloying metals and in high-speed tool steels (up to 9 per cent) to replace part of the tungsten content; in addition, metallic molybdenum, in smaller quantities, is essential in incandescent lamps and radio tubes; molybdenum salts, for enamels and pigments, and as chemical agents. Substitutes: tungsten, platinum, nickel. Ore treatment: fine grinding and flotation. Recovery (Climax): 89 per cent; power requirement, 11.6 kwhr/ton of ore (0.6 per cent MoS_2 feed); water requirement, 1.1 tons per ton of ore.

Niobium (columbium) and tantalum. Ore: $(Fe,Mn)(Nb,Ta)_2O_6$, 000 characterized as columbite when niobium predominates and as tantalite when tantalum predominates.

Niobium: uses, primarily as an alloy (up to 3 per cent Nb) to stainless steels to reduce corrosion at high pressures and temperatures, as for turbines, projectiles, and rockets. For the preparation of ferrocolumbian, columbite must have an Nb:Ta ratio of 5:1. Substitutes: not known.

Tantalum: uses, as a metal in radar and other electronic tubes; tantalum fluoride, as a catalyst in making synthetic rubber; also for cutting tools — tantalum carbide compares in hardness with diamonds and tungsten carbide as an abrasive (melting point 6917°F). Substitutes: in part, tungsten. Ore treatment: carefully controlled crushing and sorting; dissolution in HF and chemical separation of niobium and tantalum fluorides; electrolytic reduction and sintering in vacuum.

Nickel. Ores: pentlandite (Fe,Ni)S, generally as an inclusion in pyrrhotite ($Fe_{11}S_{12}$) with copper (Ni:Cu ratio, approximately 1.8–2.0:1), and garnierite ($H_2(Ni,Mg)SiO_4 \cdot H_2O$). Utilization (percentages of total in 1947): corrosion-resistant nonferrous alloys (e.g., Monel metal), 34 per cent; low-nickel steels (0.5–0.7 per cent Ni), for transportation equipment and machinery, 21.5 per cent; stainless steels (7–35 per cent Ni), 19 per cent; electroplating, especially glass seals in vacuum tubes, 11 per cent; high-temperature and electrical-resistance alloys (e.g., nichrome), 6 per cent; also nickel cast irons, catalysts, ceramics, storage batteries, and other uses. Substitutes: scrap nickel (10 per cent of U. S. total supply in 1947); chromium, manganese, molybdenum, and cadmium (for stainless steels and plating). Ore treatment: crushing, magnetic separation, and differential flotation, to produce concentrate (ca. 3–4 per cent Ni). Recovery, 85–90 per cent. Power required, about 19.6 kwhr/ton of ore. Water required: 1.1–1.75 ton/ton of ore. Subsequent smelting to produce matte (ca. 75 per cent Ni); final electrolysis to produce metal (high power requirements).

Petroleum, natural gas, and asphalt. Composition: complex, variable hydrocarbons of organic origin accumulated in structural traps. Range in volatility from natural gas to asphalt.

Petroleum: uses, primarily a fuel, but also a major source of lubricants, chemical raw materials, construction materials, etc. U. S. consumption in 1926, 1937, and 1944 may be broken down as shown in Table 94. Substitutes: natural gas, bituminous coals, oil shales.

Production: the efficiency of petroleum recovery is determined by 000 oil-well drilling techniques, particularly the maintenance of gas pressure (which permits up to 80 per cent recovery); by the adequacy of storage and transportation facilities; and by refining methods (especially catalytic cracking).

Natural gas: uses, principally as a fuel, in various forms — as an untreated gas, mixed with manufactured gas, converted into natural gasoline (at about 1 gallon per 1000 cu. ft.), or into 100-cetane diesel fuel. Also important as a source of carbon black, essential for the manufacture of synthetic rubber and various plastics; of hydrogen, for the production of synthetic ammonia, HCl, and methanol, for the hydrogenation of oils, and for metals fabrication; finally as a source of waxes. Out of 1947 U. S. natural gas consumption, 11 per cent went to carbon-black plants; 8 per cent to conversion into natural gasoline and diesel fuel, and the rest was consumed directly as fuel. Substitute: manufactured gas (lower heat value). Production: as for petroleum.

TABLE 94

Utilization of petroleum, United States, 1926, 1937, 1944 (percentages)

	1926	*1937*	*1944*
Crude petroleum run	93.9	88.2	98.7
Recovery			
Gasoline, straight run	—	19.3	16.2
cracked	—	20.6	23.2
total	36.1	43.9	39.4
Kerosene	7.4	5.5	4.7
Fuel oils	44.0	38.6	42.1
Lubricants	3.9	3.0	2.5
Wax	—?	0.1	0.2
Coke	—?	0.5	0.5
Asphalt	2.3	2.0	2.3
Road oil	—?	0.7	0.1
Still gas	—?	5.2	6.1
Refining losses	(6.3)	0.8	0.8

Asphalt: sources, by-product of petroleum refining, bituminous rock, and allied native asphalts. Uses: in construction, for paving, roofing, and waterproofing (about 80 per cent of the total); for the manufacture of coal briquettes; for manufacture of molded products, especially electrical fittings; for blending rubber; in paints and enamels, etc. Substitutes: cement, for paving; synthetic plastics,